Vol. 24, No. 8 August, 1927

THE
PSYCHOLOGICAL BULLETIN

THE ACQUISITION OF SKILL[1]

BY JOHN A. McGEOCH
Washington University

I. LEARNING

Definitions of Skill and Practice. Pear (**94**) analyzes the right and wrong uses of the term "skill" and proposes to define it as an "*integration of well-adjusted performances,* rather than a tying together of mere habits." In skill worth the name the habits involved are of a special kind, interacting to give an adequate adaptive act which is more than the sum of its parts. This definition fits with some exactness the skills included in this review. Maze learning, mirror-drawing, typewriting and other skills are certainly more than the sum of serial habits, but represent, rather, an integration into a unitary response. Skills are, however, continuously distributed, and may vary in the complexity of the integration from cancellation, perhaps, at one end to typewriting or language at the other. In another connection, Pear (**93**) has used the definition quoted above, discussing in the light of it some of the work on skill, particularly that of an industrial nature.

G. S. Gates (**44**) has studied the definitions of the term "practice" in a number of representative books and papers and finds at least four distinguishable meanings: (A) processes occurring in the subject when an act is repeated; (B) a certain kind of consciousness;

[1] This review covers the period beginning January, 1917. It includes only papers which are primarily experimental, with the exception of two on the definition of terms and one historical paper. Papers reporting tests of skill and motor ability; academic skills, such as reading and writing; practice effects incidental to other experimental problems; apparatus; and theories of learning are not included. Not all references are mentioned in the body of the review.

(C) the act of repeating, when repetition is accompanied by improvement; and (D) mere repetition, whether or not accompanied by improvement. She proposes that the term be used in the widest sense of the repetition of any function. Then we can ask: what are the results of the repetition? It might be added, however, that this definition would fail to distinguish a learning experiment from one on work, unless one were to regard the purpose of the experiment and the point on the curve at which study begins.

The Form of the Learning Curve. In a majority of the studies reporting learning curves, the general characteristic of negative acceleration appears. It will be significant, therefore, only to point out exceptions to this finding, together with certain other special features.

Departing from a discussion of Swift's early experiments on ball-tossing, Peterson (**100**) inquires what data are most significant for the learning process. Twenty-six subjects practiced ball-tossing at each period until each had made 200 catches, and practice was continued until each subject had gone through five periods without error. Scoring was in terms of errors. Peterson concludes that the learning curves for ball-tossing resemble those for other functions, provided similar kinds of data are compared. The error curve accelerates negatively, while that for the average number of catches per trial accelerates positively, as did Swift's curves. Neither of these curves can be taken as entirely indicative of the process of learning, since other forms of plotting results are possible. While it is possible that the usual rapid initial rise may be a *bona fide* phenomenon, Peterson suggests the possibility that the rise may in many cases be a function of the method of stating the results, rather than representative of the learning. He believes that the whole subject needs overhauling and adequate methods for making comparable data from different experiments. He suggests a tentative procedure.

Chapman (**17**) tested 20 students at intervals of two or three hours between the 20th and 180th hours of typing practice and found distinct positive acceleration with some subjects in the period from 20 to 60 hours. This partially corroborates the finding of Chapman and Hills, who suggested in 1916 that in the improvement of a complex function positive acceleration is probably always present. Trow and Sears (**141**) have found positive acceleration in a card-sorting curve, because of the fact that the subject started on a plateau as a result of earlier intermittent practice. Parallel learning curves of an infant in voluntary control of the bladder and in vocabulary have

been studied by Hull and Hull (**64**). The curve for bladder control is negatively accelerated, while that for vocabulary accelerates positively. They suggest that the latter may be an example of analytical learning like Ruger's puzzle curves and Hull's for the evolution of concepts.

The acquisition of skill in walking a 3/16 inch wire, 360 inches long, on which a definite tension was maintained, has been plotted by G. B. Johnson (**70**). Under one condition the wire was 36 inches from the ground and under another it was 72 inches. The subjects practiced on alternate week days. The curves for both heights of the wire show slight positive acceleration. At each trial the subject walked as far as he could before falling, the score being the number of inches covered successfully. Such data are not, however, comparable with those of Peterson for errors, for example.

Kelley and Carr (**72**) have published learning curves for typesetting obtained under school conditions and based on the entire record of the subjects, rather than on tests only. The subjects were apprentices at the Lakeside Press, Chicago. The speed curves were of the usual type, but the error curves were unique, increasing during the first 12 jobs, then falling rapidly.

A particularly sharp initial spurt was found by Norcross (**92**) in adding machine listing, the improvement of the first day being more than for all succeeding days. Book (**9**) thinks that the rapid initial progress in typewriting results from the fact that learners are making progress along all lines at once, a conclusion not corroborated by Swift's early findings.

In a study, one of the aims of which was to discover the influence of the type of function involved in learning, using 120 school children as subjects and card-sorting, substitution and abstract relations as materials, Ruch (**125**) concludes that there is no reason to assume that there is any one type of practice curve independent of the function practiced and of differences in the general mental ability of the subjects undergoing the practice. Chapman (**17**) finds no typical curve for typewriting, and Gellhorn (**49**), using cancellation, addition and multiplication, with subjects of varying ages, finds that the form of the practice curve is characteristic for each subject, regardless of the material learned. The form of Schriever's (**126**) curves is likewise independent of the material.

Snoddy (**129**) divides the curve obtained from practice with the stabilimeter, a mirror-tracing device with electrical connections, into two parts; an adaptation portion dependent on growth processes, and

a later facilitation portion resulting from condensation of the neuromuscular pattern formed by the growth.

Many of the papers reporting negative acceleration point out differences in regularity, slope and so forth, resulting from the materials used, type of subject, or practice condition. The variations from the customary form of the learning curve, noted above, are, however, particularly significant. They forfend a too ready acceptance of the customary result as final, and point to a complexity of learning function, our understanding of which is in its initial stages.

Plateaus. Attention has been given to the explanation of the plateau phenomenon by Book(9), Freeland(39), Hull and Hull(64), Trow and Sears (141) and Swift (134). In his *Learning to Typewrite,* based largely on the experimental findings of his earlier work, *The Psychology of Skill,* Book explains the plateaus in his typewriting curves by slumps in attention occurring at points where difficulties multiply. To this explanation Swift objects that it does not explain the marked rise after plateaus, that it is unverified by other investigators and that it fails to satisfy the facts about plateaus. He insists that any explanation must take account of the rather sudden rise which follows plateaus, and that automatization of associations during the plateau period does this satisfactorily. Freeland has studied the typewriting curves for six normal children. Plateaus occurred with all subjects, caused particularly in one case by four difficulties: incorrect placing of the hands, insufficient firmness in holding the shift key, failure to space; and to keep the eyes on the copy. While this explanation, as stated, is not coördinate with those of Book and Swift, it points out the specific difficulties leading to a particular plateau.

In the curve for bladder control by a young child, reported by Hull and Hull, a pronounced plateau appeared, beginning at the 18th four-week period and continuing for nine lunar months. The difficult early stages of talking coincided exactly with the beginning of this plateau, and the authors suggest that learning to talk may have interfered with the acquisition of bladder control. Interference due to conflicting methods of practice is advanced by Trow and Sears in explanation of the plateau occurring in their curve for card-sorting.

Plateaus have also been noted by Brooks (11) and by Towne (140). Chapman (17) finds short plateaus in typing curves, but not at any fixed points. Peterson (100), on the other hand, reports an almost complete absence of plateaus in both individual and average curves for ball-tossing, as do Buford Johnson (69) in

a study of dart throwing and Norcross (92) in adding machine listing.

Equations of the Learning Curve. Thurstone (139), after experimenting with some 40 different equations on published learning curve data, has developed an empirical equation for the study of the customary negatively accelerated curve, giving equations both for a curve which passes through its origin and for one that does not. He considers equations for speed-amount, time-amount, time-time and speed-time curves. This formulation of the relation between repetition and attainment not only gives scientific satisfaction, but makes possible prediction of the limits of practice, statement of how much preceding practice the subject has had, and other kinds of learning function analysis. Blair (6), departing from an earlier paper by Thurstone before the American Psychological Association, criticizes his equations, and for that matter all similar ones, insisting that correct values for the constants are impossible because we do not know the true zero-point for practice.

Meyer (87) gives much credit to Thurstone's pioneer work, but is unable to follow it because it is not based on sufficiently "rational" considerations. He then proceeds to define the variables and constants, and to give methods for the numerical determination of the parameters, developing what he considers a more rational equation. Eppright (87) adds a second method for determining the first three of Meyer's constants. Meyer (88) has used his equation in studynig the effect of alcohol, tobacco, and tea on writing shorthand exercises.

Distribution of Practice. In two significant papers, Pechstein (95, 97) has demonstrated, with a four-section maze problem, the interrelations of the two old problems of *whole vs. part,* and *massed vs. distributed practice.* Massed practice is very unfavorable to the whole method, while all types of the part method give favorable results when practice is continuous. "The hard problem becomes easy if it is learned under massed conditions by the part method, and in no other way." McClatchy (86) interpolated a 48-hour rest period after the 1st, 3rd, 5th, 7th, 9th and 11th trials on a maze, in an effort to discover the optimal position for such rest. For the criteria of time and trials, the optimal locus was at the end of the 7th trial. Insertion of rest at any other point in the learning was detrimental. With a 24-hour rest period, the optimal locus was early in the learning, between the first and fourth trials. These results were checked against a control group. They suggest that the rest

period should not be constant for all stages of learning, but that short rests early and long ones later might be beneficial.

Cummins (22), using single column addition, and division, with school children, compared a reducing schedule, by which time and repetitions decreased and length of interval increased, with an equal schedule, by which time, repetitions and interval remained constant throughout, and found the reducing schedule superior. For mirror-drawing, Gopalaswami (50) finds two runs on the first day and five runs on subsequent days better than four on the first day and ten on succeeding days until complete mastery is attained. Reed (119) has compared a continuous hour of practice at addition problems with 20 min. daily, 10 min. daily, and 10 min. twice a week for three weeks, finding that all forms of distribution are better than the continuous hour, but show small differences among themselves.

Using a form of mirror-drawing, Snoddy (128) finds that a recess period in the early stages of learning aids accuracy, and continuous repetition in the later stages makes possible the attainment of speed. Dearborn and Lincoln (28) report that two periods are slightly better than one long period for practice on three kinds of substitution and a dotting experiment.

Part and Whole Methods. Pechstein's conclusion that the part-massed method of learning is beneficial has already been stated. He has also studied (95) the comparative efficacies of the whole method and various forms of the part method beside the pure part, notably the direct repetitive, by which the subject learns Section 1 of the maze, then 1 and 2 and so on; the reversed repetitive, by which the subject learns Section 4, then 3 and 4 and so forth; and the progressive part, by which the subject learns Section 1, then Section 2 and then connects them. The same four-section maze was used, the subjects being given one run daily for four days, then two runs daily until mastery. Pechstein finds that the whole method is superior to the pure part, but that the progressive part and direct repetitive methods are superior to the whole method. "The strength of all types of improved ('modified') part methods rests upon the progressive elimination and distributive handling of the emotional and positional factors, together with the inherent advantages of any 'part' procedure." Pechstein (96) has also analyzed the elements of waste incident to the pure part method, and finds that "all the waste in part learning occurs in the act of connection and is here traceable almost entirely to the influence of place association."

The whole, pure part, and part continuous (Pechstein's direct

repetitive) methods have been studied with the maze by Barton (4), who finds that both part methods are superior to the whole method by the criteria of time and errors, while the pure part alone is superior when judged by trials. Gopalaswami (51), using mirror-drawing, has studied the whole, pure part, two part, and progressive part methods under various conditions of temporal distribution, and has found the progressive part (distributed) superior and the whole method (distributed) the poorest. He interprets his work as corroborating that of Pechstein. Somewhat related is the conclusion of Barton (5) that comprehensive learning of complete composition material in typewriting is better than practice on meaningless and isolated material.

Koch (76) has compared a group, practicing with one hand at a time playing sequences on a typewriter keyboard and later combining the hand movements in simultaneous playing, with another group practicing both hands simultaneously. Each subject struck the keys in time with a metronome set at 140, practicing three minutes and resting two minutes for an hour, or, if necessary, at later periods until complete learning was attained. Nine out of ten possible comparisons favor the part method in terms of trials, regardless of the previous piano skill of the subject. The difference in terms of errors is not so great. Measured in terms of errors per trial the whole method is more accurate, but elimination is more rapid with the part method.

The distinct superiority of the part method in learning to solve cardboard puzzles has been shown by Mather and Kline (85). They suggest as reasons that the part method gives more immediate repetition than the whole, keeps harder problems in abeyance until simple ones are mastered, and eliminates the tendency to retroactive inhibition possible in this kind of problem.

The Influence of Incentives. The precise definition of an incentive is somewhat in doubt, but under this head we shall include knowledge of results, encouragement and related factors. Book and Norvell (7) have investigated the influence of knowledge of results, and interest in work, upon the rapidity of improvement. An experimental and a control group practiced making the small letter "a," cancellation, substitution and mental multiplication. The stimulus or experimental group were asked to count and record their scores "and in other carefully planned ways were interested as much as possible in the improvement they were making. They were also made to feel that they could increase their score in practically every practice and test."

The stimulus group improved much more than the controls, both in speed and in accuracy, but suddenly ceased to gain when the incentive conditions were removed; while the control group which had been making little progress began suddenly to improve when the incentives were applied. In *Learning to Typewrite* Book frequently stresses the value of such incentives. Chapman and Feder (19) have used incentives somewhat similar to those used by Book and Norvell, with a beneficial effect, but Colburn, Collins and Myers (21) report that, in fitting cubes into a box, the learner's knowledge of his speed of performance hinders rather than helps.

The effect of practice without knowledge of results has been studied by Spencer (130), who repeated Judd's 1905 experiment, having subjects place a dot behind a screen upon what they took to be the true extension of a visible line. Spencer treats the errors purely as errors of amount, without regard to direction, and finds improvement without knowledge in three out of four cases. Freeland (40) reports that casual practice, without plan or end, results in little improvement in basket-throwing.

Gates and Rissland (46) find, in motor coördination and color naming, a slight difference in favor of either encouragement or discouragement, rather than mere repetition without either; and an advantage for instruction to work at maximal speed is reported by Grünthal (55). Arousal of special interest in typing caused one of Freeland's (39) subjects to break a plateau. Book (9) has shown that the world champion typing speed has increased from 82 words per minute in 1906 to 147 words in 1923, although in 1906 it was thought that the physiological limit of this skill had been reached. This increase he ascribes to the influence of competition and belief in the possibility of progress on the part of learners.

A striking increase in the output of 40 hand compositors at the Lakeside Press under the influence of a wage-incentive has been found by Kitson (74). The average time that these men had worked as printers was 10.3 years, yet the average output increased 78 per cent in five months, the increase continuing during the first 20 weeks.

Punishment for inaccuracy in multiple choice reactions has as one of its results rapid adoption of a learning plan and care in avoiding errors, according to Rexroad (120); and Burnett and Pear (12) suggest that the problem of motivation is among the most important in the psychology of skill.

The Influence of Intelligence. O. J. Johnson (71) had 60 students practice mirror-reading 10 min. daily for 20 days. Six intelligence

tests were given to them during this time and the average scores correlated with the average number of words read per day and with improvement, measured by the difference between the mean number of words read in the first three days and the mean of the last three days. In the first case, r is 0.34 and in the second 0.46. Johnson also compares the upper and lower halves of the group, and concludes that the bright subjects improve more than the less bright. Peterson (107) has analyzed Johnson's data and has shown that, if the *time required to do a given amount of work* had been used, the conclusion would have been reversed. He has also computed the harmonic and geometric means, and the percentage that the better group average is of the poorer group average and has shown that, in terms of these measures, the poorer group improves more than the better group.

When subjects with an I.Q. range of 75 points are classified into superior, average and inferior groups, Ruch (125) finds that the curves may converge, as with card-sorting, remain parallel, as do the code substitution curves, or diverge as with the rate scores of an abstract relations test. Ruch believes that many disagreements might be harmonized on the hypothesis that learning curves are specifically conditioned both by the function studied and by differences in the mental capacities of the subjects. The abilities of three groups of varying intelligence, from the Bedford Hills Reformatory, to learn to throw darts at a target were compared by Buford Johnson (69). The high group (average intelligence) had the greatest initial ability and the highest final average. The low (feeble-minded) group had the lowest averages. While the higher mental level is the more effective, the upper grade mental defectives show a great capacity for improvement. Analysis of the modes of attack shows that other than intellectual traits are also involved.

Haught (58) has computed correlations between the Stanford-Revision and two rational learning tests, a checker puzzle and Tait's Labyrinth Puzzle. Rational Learning (modified) correlated most highly with the Stanford-Revision and the Checker Puzzle lowest. Both rational learning tests measure mental functions not detected by the intelligence test. Peterson (102) reports a correlation of 0.86 between rational learning and estimated intelligence. He also states (102, 104) that the rational learning test predicts with high accuracy what a subject's performance in general psychology will be. G. B. Johnson (70) states that superior intelligence is an asset in learning to walk a tight wire, and Ruch (125) finds that the correla-

tions between the Stanford-Revision and his learning tests run, in increasing order of magnitude, card-sorting, code substitution, abstract relations. L. S. Hollingworth (63) summarizes work by Hollingworth and Cobb, comparing two groups lying in the highest percentile of intelligence quotients, one having a mean I.Q. of 146 and the other of 165. The groups are similar in age, sex, race, home conditions and educational opportunity. The higher group proves the more educable, particularly in the more complex tasks. Race (116) likewise reports that superior children gain significantly more than average children in addition, multiplication by substitution, and language completion, while in digit-symbol substitution Root's (123) superior subjects surpass the non-selected group considerably. Koch and Ufkess (77) find that degree of intelligence is one factor in the determination of maze learning ability.

A high correlation between maze records and both Army Alpha and Thorndike scores has been found by Warden (145), and Hunter (59) reports a correlation of —0.45 between time records and Otis scores. The other maze criteria give low negative correlations with Otis. Wembridge and Gabel (149), in a multiple choice experiment with children, find a significant correlation between mental age and learning ability, and Abel (1) asserts that a normal intelligence level accompanies ability to receive skilled training. Dallenbach (23) concludes that feeble-minded children improve slowly in visual apprehension and that such improvement is indicative of backwardness.

Different results have been obtained by other experimenters and under other conditions. Capacity in serial action is only slightly related to Army Alpha, according to Hansen (57), while with analogies and mirror-reading, superior subjects show less capacity for improvement (Perrin, 98). There is no correlation between card-sorting and intelligence, although there is a coefficient of 0.48 between the highest gain and intelligence (Myers, 90). In sorting gun wads (Woodrow, 150), feeble-minded children show the same amount of improvement and follow the same practice curve as children of the same mental age and initial ability.

The Influence of Guidance. Five significant experiments on the effect of tuition have issued from the Chicago laboratory. The first, by Carr (14) was concerned with visual guidance, using a maze so constructed that the culs-de-sac could not be distinguished visually from the true path, and permitting vision for varying portions of the learning. In all cases, visual control was more effective in

reducing errors than in decreasing trials. It prevented errors not only in the trials where it was permitted, but in the post-visual period also. Three and five guided trials had the most beneficial effect, the effectiveness of the guidance not being in proportion to the amount, however. Carr also permitted his subjects to study maps of the maze, and found that this reduced both errors and trials, especially the former. Some of the conditions of this experiment were repeated by Carr and Osbourn (**15**). The subjects were allowed to see the movements of both hand and stylus, but the maze was obscured by a thin aluminum plate attached to the stylus in such a way as to cover the maze for all possible positions of the stylus. Again vision was always effective in reducing trials and errors, particularly backward errors. When vision was introduced after some experience without vision, some of the subjects were much confused.

Mechanical guidance was given to both animal and human subjects by Miss Koch (**75**), by blocking the entrances to the culs-de-sac. This type of control proved more effective for rats than for human subjects, for whom it was sometimes detrimental. Within limits, the efficacy of the mechanical control varied directly as the distance of the guided runs from the initial trial. Miss Koch gives a careful analysis of the modes in which the control may function. Miss Ludgate (**84**) guided subjects manually over the true path for varying numbers of trials. Initial guidance was beneficial, the amount of guidance which gave the best results being a function of the maze employed and of the criterion used. Her results "support the conclusion that error prevention in any portion of the early stage of the learning is more valuable than the making of errors and their subsequent elimination."

Two forms of verbal tuition have been used by Wang (**143**): instruction, in which the subject was told in detail in which direction to move the stylus; and information, in the major form of which the experimenter counted aloud after the completion of each error. The instructional method was more effective than the informational, but both operated to decrease both errors and trials. The optimal number of controlled trials was four for the instructional method and eight for the informational. Superfluous trials with guidance increase both trial and error records. It has been the general result of the guidance experiments that given amounts are effective, but that guidance beyond a certain point either has no beneficial effect or is actually detrimental. All of these papers on tuition have contained much relevant detail which cannot be mentioned here.

Gray (54) concludes that substitution learning is aided by the explanation to the subject of a system which brings into relation all of the letters of the alphabet, and Book (9) repeatedly emphasizes the advantage which learners may derive from guidance by teachers of typewriting. Norcross (92) reports that observation of other subjects is beneficial in simple listing on the adding machine.

Gates and Taylor (42), on the other hand, fail to find any advantage, with young children, of tracing letters on thin paper through which the models could be clearly seen, over writing from copy, and Lavin (82) states that in learning to make hand movements, as in tracing designs, learning is retarded, if the experimenter guides the subject's hand in making the original movement. The optimal condition is to have the experimenter make the tracing, while the subject watches.

Transfer of Training. Webb (147), using four pencil mazes, found a positive transfer effect in all cases, the degree being a function of the first problem and of the direction of transfer. The locus of transfer was confined to the first five trials, and the effect was slightly greater on retracing than on other errors. There was a positive correlation between both degree of transfer and the difficulty of the first problem, and similarity and amount of transfer. Pechstein (95) likewise reports a progressive increase in transfer from one to another of the sections of his maze. He gives the items of transfer as general attitude, consciousness of power, emotional attitude, and specific items referring to details of the maze pattern. The part method permits transfer to operate at its full value. That transfer will explain the advantage of part methods is suggested by Barton (4), who agrees with Pechstein in finding positive transfer from one section of a maze to the other, when the sections are learned as parts.

In terms of trials, transfer was invariably greater from Ludgate's (84) manually guided trials than from unguided learning. The same was true for errors in one order of transfer. The greater the amount of initial guidance, the greater the transfer. Hunter's (65) Vincent curves show a large amount of transfer from a maze habit to its reverse.

Every case, in an experiment performed by Norcross (92) in work with an adding machine, shows clear evidence of bilateral transfer, which he ascribes to changed emotional attitude, and improvement of general habits, such as concentration. A further important finding is that practice in reading numbers from a work sheet, without

operating the machine, gives more improvement of the idle hand than practicing that hand on the machine without number reading. In every case, also, Ewert's (35) mirror-drawing subjects show improvement of the idle hand, although less than that formerly reported by Starch. The same general conclusion is drawn by Fildes (36) in mirror-writing, and Koch (76) finds considerable evidence of positive transfer from one hand to the other in typewriting letter sequences. Lavín (82) reports almost perfect bilateral transfer in design tracing, and Langelüddeke (81) finds such transfer in typing.

Positive transfer appears in the work of Mather and Kline (85), where knowledge gained in solving one puzzle transferred to the next, " provided that similarity of parts and of plans was recognized," which was usually the case; and in Noble's (91) study, where transfer appeared from practice at throwing basket-ball goals from the foul line to practice under an artificial situation simulating a game. He accounts for this by the similarity of the movements in both cases. Downey and Anderson (31) find some transfer in simultaneous reading and writing from one verse to another, and Pyle (112) reports great transfer from one system of numbering card-sorting compartments to a second system. This is explainable in terms of the identical elements involved. In Woodrow's (150) work with normal and feeble-minded children, there is some transfer effect from practice at sorting gun wads to a series of motor end-tests, but there is no difference between the two groups in this respect. Dowd and Arlitt (30) find no difference between supervised play and formal gymnastics in their transfer effects upon other tests.

J. C. Peterson (99), studying problem solution with a problem which permitted of indefinite expansion, found a large amount of transfer, both positive and negative, with the former predominating. The amount seemed to be a function both of objective similarity and of the generalizing activities of the subject. Wooster's (151) subjects evidenced a large amount of transfer from the learning of a new spatial coördination to other experimental and practical conditions.

A majority of the papers mentioning transfer report either clear positive or negative results. There are a few in which no clear transfer occurred, as in the work of Dearborn and Brewer (27) and Dearborn and Lincoln (28). Peterson (105) discovers no carrying over of effect from one part of a mental maze to another, and Gates and Taylor (42) find meager transfer from tracing letters to writing them.

Warden (**145**) reports a significant intra-pattern interference within the single integrated maze habit, in which a series of movements will be carried over from one stage of learning to a later stage. The amount of this intra-pattern transfer increases consistently with the number of trials required to learn, although it is not causal to slow learning. This negative transfer is greatest with those subjects who use the motor method of learning, next greatest with those using the visual method, and least with the word reaction method. Webb (**147**) concludes, as a result of his study of retroaction, that such inhibition can be explained largely in terms of transfer and that, in so far as this is true, retroaction is not a phenomenon *sui generis*. Further discussion of Webb's work will be found under retention.

Formation of More Than One Habit Simultaneously. This problem is closely allied both to negative transfer and to the part-whole problem. One of Pyle's (**112**) groups distributed cards for 15 periods into compartments numbered without system, and then for 15 periods with the same numbers but on different compartments. A second group alternated from one numbering scheme to the other for 30 days. "The inference from this experiment is that it is not economical to form at the same time two mutually inhibitory sets of habits. The better procedure is to form one, and then the other." Dashiell (**24**) has made an extended study of the relative merits of the complete versus the alternate method of forming two habits, using several different kinds of learning problems. He finds that, in all the forms of double habit formation studied, the complete method, by which the subject learns one habit and then the other, is more economical than the alternate method, by which the subject practices the two habits alternately. This is true for several different criteria. Dashiell (**25**) has used this general technique in a study of the experimental isolation of habits of different levels of complexity, finding clear differentiation in rates of learning at the different levels.

Chen and Carr (**20**) found, in studying the ability of Chinese students to read in vertical and horizontal directions, that subjects with the least training in English did better with vertical Chinese and horizontal English and Arabic; subjects with maximum English training did as well or better with the horizontal arrangement of Chinese, while those with moderate training in English had some difficulty with vertical Chinese and horizontal English letters. This is probably due to the interference of two habits of perhaps roughly equal strength.

In typewriting, Book (9) states that all orders of habits should be practiced together, and Langelüddeke (81) finds all orders developing together from the beginning.

Modes of Attack. Employing the same maze used in several of his other studies, a maze with a single type of blind, Warden (145) finds that less than 30 per cent of the subjects use the supposedly typical motor method of attack, while more than 40 per cent use either explicit or implicit verbalization, the remainder using visual imagery, which is probably either verbal, motor, or both. Of these methods, the word-reaction was by far the best, visual imagery coming second, and the motor method a poor third. If these results are typical, and it is probable that they are, the validity of the customary comparisons between animal and human learning is called into question. The methods are probably not identical, since the human subject utilizes short-cut methods not in the animal's repertoire. Rexroad (121) reports that verbal responses are of great importance in learning to make multiple choice reactions. Snoddy (128) states that the mental image of a movement cannot control the movement.

Koch and Ufkess (77) have compared 19 blind subjects, paired in age and intelligence, with seeing subjects, with the result that the blind are found to be somewhat less successful in maze learning, particularly by the criterion of errors. Some visual experience prior to the onset of blindness reduced the handicap materially. Gault (47, 48) has shown that deaf subjects can be taught to interpret speech through the medium of touch, and Thurstone (138) reports that the visual study of a printed code is superior to both phonetic and synthetic methods of teaching radio telegraphy.

Space Relations. Wooster (151) has investigated the acquisition of a new spatial coördination. She used two 40 degree optical prisms, producing an angular deviation of 21 degrees, and worked with binocular vision. The subjects were to build up a new coördination under the changed conditions. The new habit followed the customary course of learning. Its development was conditioned by a definite localizing activity on the part of the subject. Sound was not an effective factor, while vision, contact and kinaesthesis were very effective. Warden (146) asked his subjects to reproduce the maze pattern under various conditions immediately succeeding learning. The maze was the one-type alley maze used in the other studies reviewed. Non-visual reproduction was more accurate than visual. While most of the subjects had entered all blinds, 90 per cent underestimated the number. Most of the subjects estimated the maze to

be much larger than it was, and were highly inaccurate in their other estimations. They had learned the true path, but not the various space relations incident to the learning.

Characteristics of Experts. The voluntary motor ability of 48 winners of state and district typing contests, 5 ex-champions, and 65 students of typewriting has been studied by Book (8). World champions and ex-champions possess exceptionally high voluntary motor control, and such control "was present among all the contestants in the last international contest in almost direct proportion to the skill in typing which each displayed." A comparison of beginners with experienced typists showed that this control had not been developed by practice, but rather it conditioned fast improvement through practice, and is a necessity for the attainment of the highest levels of skill.

The performances of athletes and non-athletes in several motor coördination tests have been compared by Dorcus (29), with the result that athletic men and women were superior to the non-athletic groups. Where improvement occurred, the athletes showed in general the greater improvement. An expert marksman, tested by Gates (41), possessed good vision, superior motor control and coördination, superior eye-hand coördination, and ability to resist distraction. Lipmann (83) contributes an analysis of the mental functions involved in radio telegraphy. Sending demands good memory, regular rhythm, resistance to distraction, and rapidity of reproduction of the code. Receiving demands preferably a man of auditory-objective type, good auditory acuity, and distributed attention.

Nature of Improvement. Gates and Taylor (45) have made an important analysis of the character of improvement through practice by young children in a motor function. The function studied was tapping on sheets of paper, from which good practice curves were obtained. One of their conclusions well states the conditions: "A group of children who were given no practice between the eighteenth and ninety-fourth days were, in their first tests after an interval of no training, better than on the eighteenth day but inferior to the equivalent practice group on the ninety-fourth day. The unpracticed group improved rapidly, however, and in about ten days were equal to the trained group." The authors interpret these results to mean that improvement in tapping is due primarily to the acquisition of working techniques and adaptations to conditions, and to the maturation of the mechanisms involved, although long training did not

affect this maturation. Race (116) concludes that improvability is specialized.

Primacy-Recency-Frequency and Backward Elimination. Employing a maze with a single type of cul-de-sac, thus securing, theoretically at least, a perfect homogeneity of unit coördination, Warden's (144) subjects eliminated first the group of culs-de-sac near the entrance, next the group near the goal, and last the intermediate group. He concludes that, when all conditions other than serial position of culs-de-sac are equal, a primacy-recency order of elimination is the typical order. With this conclusion, Peterson's (105) mental maze results agree only in part, and Lavín's (82) design tracing data indicate that the beginning and end of the movements are learned first. In the work of Wang (143) on verbal guidance, the blinds at the entrance and goals were, in general, eliminated first, but the definite temporal order of elimination " seems to be a function of the peculiar position of the culs-de-sac in the maze."

With very different experimental materials, namely, estimation of lengths, surfaces, shapes, adding letters to make words and similar problems, Thorndike (136) tests the orthodox doctrine of primacy, finding that there is no superiority for primacy or, for that matter, for recency.

The work of Peterson (105) just mentioned was primarily concerned with the backward elimination of errors in the learning of a mental maze, a learning problem independent of the spatial factors inevitable in the stylus maze. His results show a clear case for backward elimination of blind alley entrances and for the earlier elimination of return runs after blind alley entrances than of the entrances themselves. His learning results are carefully compared with probability expectations. In Barton's (4) study a general regressive order of elimination appeared, although under somewhat different conditions from those which prevailed in Peterson's work. Warden (144) failed to find with a stylus maze any evidence of a regressive order of elimination.

In a later paper, Peterson (106) uses a mental maze with the same procedure, except that after each wrong choice the subject is immediately brought back to the entrance and started over again. This gives a situation in which frequency and recency influences are against the solution of the problem. With this technique, errors are eliminated in the forward direction, whereas in the previous paper the opposite tendency appears. Peterson concludes that " agreement with recency has no relation at all to the rightness of the response,

and in the case of frequency, agreement with the law is somewhat more likely to occur in the wrong than in the right responses." Thus, learning goes on in spite of, rather than because of recency and frequency. This conclusion applies, of course, to the general modification of the order of successive responses and elimination of irrelevant acts, not to the fixing of acts in a determined series. J. C. Peterson (99), using rational problems, states that " the most obvious factors in the selection and accentuation of essential elements were frequency of repetition of elements and their relative nearness to a goal or end of action."

Accuracy vs. Speed. Sturt (133) has attempted an experimental answer, with typewriter learning, to the question whether it is better to emphasize speed or accuracy from the start. If attention is directed solely to accuracy, speed will gradually improve, while, if attention is directed solely to speed, accuracy will tend to diminish. Book (9) believes that, in learning to typewrite, the emphasis should be on accuracy first and speed afterwards, and Hansen (57) finds that, in serial action, accuracy degenerates as speed increases, unless a rigid habit of accuracy is built up from the very beginning.

In the typewriting learning of young children, Freeland (39) reports accuracy harder to improve than speed. Speed fluctuates more than accuracy and the two are independent variables. With the latter conclusion the cancellation results of Michaelis (89) agree.

The work of Hoke (61) is not directly concerned with this problem, but has many implications for it. Hoke has endeavored to work out an ideal keyboard which will facilitate both speed and accuracy in the acquisition of typing skill. In the course of his work he finds no connection between the combination of letters with which any letter may happen to be written and the accuracy of the writing. Accuracy or inaccuracy is the result of the frequency or infrequency of the practice.

Relations Between Different Skills. Smith and McDougall (127) have attempted to test Bergson's theoretical distinction between habit and memory by intercorrelating tests of both memorizing and skill. They find two well marked groups of correlation coefficients, with little intercorrelation of the groups themselves. The less repetitive group they interpret to depend on pure memory, and the more repetitive group is taken to represent habit formation. The validity of a psychological category of " pure memory " may well be doubted, however.

In Haught's (58) work with two rational learning tests, a checker

puzzle and the Tait Labyrinth Puzzle, the common factor running through the four tests is almost zero. He interprets these data adversely to the Two Factor Theory of intelligence.

Pyle (111) has intercorrelated digit and alphabet substitution, marble distribution and nonsense syllable learning. The average intercorrelation of all tests is 0.516, and he considers that "there is probably a constant factor which may be called general learning capacity, dependent upon the characteristics of the central nervous system." The relation between stylus maze records and the Peterson rational learning problem Heron (60) finds to be small but mainly positive, the highest coefficient being 0.30. Dorcus' (29) non-athletic group gave significant positive correlations between card-dealing and steadiness, and between color-naming and card-dealing, and Brooks (11) states that "improvement in cancellation implies improvement in inverted writing." Dauber (26) obtains rank correlations of 0.50 to 0.80 between cancellation and substitution data.

Reliability of Learning Problems. Attacks upon the reliability of the maze experiment have been made by Heron (60), Hunter (59, 65) and Hunter and Randolph (66). Heron has intercorrelated the records from five stylus mazes, obtaining an average coefficient of 0.32, all criteria included. The range is from 0.02 to 0.65. The average intercorrelation of relearning records is 0.17, range 0.00 to 0.25. Heron interprets these coefficients to mean (A) that both chance and individual ability influence maze records, (B) that these factors vary with the maze problem, (C) that in no case is individual ability much more influential than chance, and (D) that in some cases chance is markedly the more influential. Within the limits of his data, Heron could not find groups of definitely equal ability.

Hunter has correlated the time scores on a simple and a complex maze, obtaining a coefficient of 0.64, showing that the same factors are at work in the two mazes. He also correlates each tenth with each succeeding tenth, time records, and discovers that the more complex habits offer the lower correlations, and that "the constellation of causal factors at work in the first tenth of learning is also about equally present in the succeeding tenths." Man shows greater stability than the rat. In another experiment Hunter obtains a correlation of 0.64 between total time on a maze pattern and its reverse, and of 0.68 between total trials. These footrule coefficients give a Pearson r. of 0.80.

Hunter and Randolph correlate six initial trials with six more after an average interval of 159.7 days. Total times give a footrule

coefficient of 0.49. Another group of subjects took six initial trials and six more after an interval averaging 59.5 days and a final six after 184.1 days. Correlations for total times range from —0.03 to 0.23. Reliability with untrained subjects is as great as with trained subjects. These results and the others in his tables of correlation coefficients lead Hunter to question the reliability of the maze experiment. His criticisms are more particularly pertinent to animal experimentation, but they are also significant here, since most of the coefficients from human data are by no means high. Carr (16) has replied to Hunter, insisting that group comparisons may validly be made under conditions where the maze is used to study differences in group performance under a specified change of conditions, for the purpose of discovering whether ability to master the maze is a function of these conditions. Hunter (67) answers Carr, holding that the units of measurement are too gross for accurate use and emphasizing the need of calibrating learning materials.

Heron (60) has also computed the correlation between a 10-letter and a 15-letter Peterson Rational Learning problem, obtaining a range of 0.48 to 0.58. Heron discusses his data in the light of theories of intelligence, interpreting his findings in support of Thorndike's view. Gopalaswami (51) obtains correlation coefficients of 0.95 (footrule translated into Pearson r.) between the sum of trials 1, 3 and 5 and of trials 2, 4 and 6 in a mirror drawing experiment. G. S. Gates (45) reports that the relationship between functions becomes higher as the individual improves through practice.

Trial and Error vs. Rational Learning. J. C. Peterson (99), studying a form of problem solution in which ideation is obviously possible, concludes that trial and error is general in learning of the problem solving type. It is conspicuous not only in the early stages, but later in forming generalizations and in their application. Joseph Peterson (102, 108) likewise finds no difference between trial and error and rational learning save in the explicitness with which the various elements are reacted to and retained for use subsequently. He thinks that even in those forms of learning where errors do not overtly appear there is a struggle between conflicting impulsive tendencies.

Mather and Kline (85) observe that their subjects use trial and error methods in the early stages of puzzle solution. These were gradually superseded by methods of "control and purpose." Gopalaswami (50), comparing so-called mechanical and rational learning, believes that there is no sharp line between the two.

Influence of Alcohol and Drugs. There have been several studies, particularly in Germany, of the effects of alcohol and drugs on the acquisition of skill. Enkling (32), Erlacher (33), Frank (38), Gylys (56), H. L. Hollingworth (62), Israel (68), Külz (79) and Langelüddeke (81) agree in finding alcohol in varying amounts deleterious to the acquisition of skill, while Riegel (122) has shown that habituation to the effects of alcohol may take place. Graf (53) finds cocain and pseudococain slightly stimulating to typewriting functions. Lange (80) verifies this result on motor skill with cocain, but finds that scopolamin and morphine have a harmful effect.

Individual Differences. Kincaid (73) has discussed critically the problem whether individual differences increase or decrease as the result of addition of equal amounts of practice. She has analyzed the data published in 24 investigations and has concluded "that there exists in general a high degree of correlation between ability at the beginning and at the end of relatively brief periods of practice. Predictability of later relative positions from reliable initial scores is comparatively safe." "By applying seven measures to the changes in differences between members of a group to these same data, we have shown that there is on the whole a preponderance of evidence among these cases for the conclusion that differences generally decrease with practice." Stoddard (132) has published a criticism of Kincaid's paper and has offered two positive suggestions for experimentation: (a) that different learning materials be used with a selected group of the same mental age and (b) on a select group with the same intial performance. Then the question can be asked: is the final deviation greater or less than it was initially?

A large number of the papers included in this review have contained incidental references to the problem of individual differences, and there have been some papers, such as those of Argelander (2, 3), Chapman (18), Gates (45), Peterson (101), Phillips (110), Pyle (111, 115), Reed (118), Ruch (125), Schriever (126), Stickland (131), Thorndike (135) and Thurstone (137), which have been principally concerned with this problem. Some of these papers have been dealt with in Kincaid's analysis. Further, since individual differences represent a problem relatively distinct from the acquisition of skill itself, and since they require a disproportionate amount of space for adequate review, no discussion of the individual findings of these investigations will be given.

II. Retention

There have been remarkably few studies of the retention of skill. Except for a few papers, retention has been purely incidental to the study of learning.

Maze Habits. To test the hypothesis of the universal applicability of the Ebbinghaus retention curve, Tsai (142) had six groups of 16 subjects each learn a stylus maze and relearn after 1, 2, 3, 5, 7, and 9 weeks, respectively. All retention curves were negatively accelerated, the amount of retention varying with the method of measurement. Saving values were invariably larger than those for recall. Retention also varied with the criterion used. Error curves were above those for time, and time curves were above those for trials. All of Tsai's values are larger than those usually obtained with verbal materials after similar intervals. The retention curves for rats studied similarly up to eight weeks are almost linear. He thinks the difference between the curves may be a result of rehearsal on the part of human subjects, the fact that human subjects learned by massed practice and the rats by distributed practice, or that human subjects employed ideational processes more than did the animals.

In her work on the effect of tuition, Koch (75) found that mechanical control introduced early in learning was an aid to retention, while that introduced in the latter part of the first 16 trials was unfavorable to retention. The accuracy of retention varies inversely as the amount of control given, while speed varies as the number of directed trials in learning.

Retroactive inhibition or negative transfer appears in Webb's (147) experiments consistently, although not to any great degree. The degree of retroaction is a function of the interpolated maze activity. Human subjects show greater susceptibility to retroaction than do rats. With human subjects, the degree of retention was a function of the maze activity and relearning records varied more widely than learning records and did not correlate with them.

Typewriting Habits. Studying typewriting with children, Freeland (39) found that long vacations caused a falling off in the work, when the function had not been well mastered, but that later, when it had been well learned, vacations had little influence. Towne (140) found no perceptible change in the effectiveness of typing habits after a break of six and a half months.

Ball-Tossing Habits. Braden (10) has published a report of ball-tossing by one subject for 100 days, the balls being tossed at a circular

hole in the top of a box. Twenty-two months and eleven days after the first experiment ended, a retrial of 18 days was taken, and 6 months and 20 days later still a second retrial of 18 days. In the first 10 trials of each part of the experiment, the number of hits was 1,029, 1,516, and 1,668, showing remarkable retention and rapid improvement through relearning.

Miscellaneous Habits. Foucault (37) asked subjects, who had formerly practiced with the Kraepelin addition sheets, to perform again after periods varying from 13 to 16 months. There was a loss of about 25 per cent, but a brief period of practice was sufficient to raise the habit to its old level. Gellhorn (49) found that, with arithmetical operations and cancellation, loss through disuse was an individual characteristic. A considerable retention of the capacity to maintain two processes (reading and writing) simultaneously, after an interval of more than two years without practice, is reported by Downey and Anderson (31). Relearning was very rapid. Some of G. B. Johnson's (70) subjects were able to return after intervals of one and two years and walk the high wire successfully on the first attempt.

Miss Wooster (151) found that a new spatial coördination, experimentally built up, was retained for long periods, " functioning at a considerable per cent of effectiveness after a lapse of from one to two years." The effect of practice upon visual apprehension in the feebleminded is relatively permanent, according to Dallenbach (23). Brooks (11), using a variety of tests, agrees with Tsai that learning which involves verbal processes is less permanent than that which involves a sensori-motor function.

The papers on retention have agreed in finding a high degree of retention of skill, even after long intervals. It is, however, to be regretted that more systematic work is not available both upon the conditions of retention and the relative retention of verbal and sensori-motor material.

BIBLIOGRAPHY

1. Abel, T. M., Tested Mentality as Related to Success in Skilled Trade Training. *Arch. of Psychol.*, 1925, **12**, No. 77. Pp. 82.
2. Argelander, A., Beiträge zur Psychologie der Übung. I. Übungsfähigkeit und Anfangsleistung. *Zsch. f. Psychol.*, 1921, **19**, 1–38.
3. Argelander, A., Beiträge zur Psychologie der Übung. II–IV. *Zsch. f. Psychol.*, 1923, **21**, 225–258.
4. Barton, J. W., Smaller vs. Larger Units in Learning the Maze. *J. Exper. Psychol.*, 1921, **4**, 418–429.

5. BARTON, J. W., Comprehensive Units in Learning Typewriting. *Psychol. Monog.*, 1926, **35**, No. 164. Pp. 47.
6. BLAIR, R. V., Thurstone's Method of Study of the Learning Curve. *Psychol. Rev.*, 1918, **25**, 81–83.
7. BOOK, W. F., and NORVELL, L., The Will to Learn: An Experimental Study of Incentives in Learning. *Ped. Sem.*, 1922, **29**, 305–362.
8. BOOK, W. F., Voluntary Motor Ability of the World's Champion Typists. *J. Appl. Psychol.*, 1924, **8**, 283–308.
9. BOOK, W. F., *Learning to Typewrite:* With a Discussion of the Psychology and Pedagogy of Skill. N. Y., Gregg, 1925.
10. BRADEN, S. R., An Extensive Experiment in Motor Learning and Relearning. *J. Educ. Psychol.*, 1924, **15**, 313–315.
11. BROOKS, F. D., Learning in the Case of Three Dissimilar Mental Functions. *J. Exper. Psychol.*, 1924, **7**, 462–468.
12. BURNETT, I., and PEAR, T. H., Motives in Acquiring Skill. *Brit. J. Psychol.*, 1925, **16**, 77–85.
13. CARMICHAEL, L., The History of Mirror Drawing as a Laboratory Method. *Ped. Sem. and J. Gen. Psychol.*, 1927, **34**, 90–91.
14. CARR, H., The Influence of Visual Guidance in Maze Learning. *J. Exper. Psychol.*, 1921, **4**, 399–417.
15. CARR, H. A., and OSBOURN, E. B., Influence of Vision in Acquiring Skill. *J. Exper. Psychol.*, 1922, **5**, 301–311.
16. CARR, H., The Reliability of the Maze Experiment. *J. Comp. Psychol.*, 1926, **6**, 85–93.
17. CHAPMAN, J. C., The Learning Curve in Typewriting. *J. Appl. Psychol.*, 1919, **3**, 252–268.
18. CHAPMAN, J. C., Statistical Considerations in Interpreting the Effect of Training on Individual Differences. *Psychol. Rev.*, 1925, **32**, 224–234.
19. CHAPMAN, J. C., and FEDER, R. B., The Effect of External Incentives on Improvement. *J. Educ. Psychol.*, 1917, **8**, 469–474.
20. CHEN, L. K., and CARR, H. A., The Ability of Chinese Students to Read in Vertical and Horizontal Directions. *J. Exper. Psychol.*, 1926, **9**, 110–117.
21. COLBURN, H., COLLINS, H., and MYERS, G. C., Some Studies in Learning. *Sch. and Soc.*, 1918, **8**, 597–600.
22. CUMMINS, R. A., Improvement and the Distribution of Practice. *T. C. Contr. to Educ.*, 1919. Pp. 72.
23. DALLENBACH, K. M., The Effect of Practice Upon Visual Apprehension in the Feeble-minded. *J. Educ. Psychol.*, 1919, **10**, 61–82.
24. DASHIELL, J. F., A Comparison of Complete Versus Alternate Methods of Learning Two Habits. *Psychol. Rev.*, 1920, **27**, 112–135.
25. DASHIELL, J. F., An Experimental Isolation of Higher Level Habits. *J. Exper. Psychol.*, 1924, **7**, 391–397.
26. DAUBER, J., Zur Entwicklung der psychischen Leistungsfähigkeit. *Fortschr. der Psychol.*, 1922, **5**, 75–141.
27. DEARBORN, W. F., and BREWER, J. M., Methods and Results of a Class Experiment in Learning. *J. Educ. Psychol.*, 1918, **9**, 63–98.
28. DEARBORN, W. F., and LINCOLN, E. A., A Class Experiment in Learning. *J. Educ. Psychol.*, 1922, **13**, 330–340.

29. Dorcus, R. M., Performances of Athletes in Coördination Tests. *J. Comp. Psychol.*, 1923, **3**, 475–499.
30. Dowd, C. E., and Arlitt, A. H., The Relative Transfer Effects of Supervised Play and Formal Gymnastics. *J. Appl. Psychol.*, 1925, **9**, 215–224.
31. Downey, J. E., and Anderson, J. E., Retention of Skill After Lapse of Practice: Simultaneous Reading and Writing. *Amer. J. Psychol.*, 1917, **28**, 396–408.
32. Enkling, J., Über die Wirkungen einmaliger und geteilter Alkoholgaben auf einfache psychische Leistungen. *Psychol. Arb.*, 1926, **9**, 274–292.
33. Erlacher, K., Über Alkoholwirkung bei Schulkindern. *Psychol. Arb.*, 1926, **9**, 293–342.
34. Ettlinger, H. J., A Curve of Growth Designed to Represent the Learning Process. *J. Exper. Psychol.*, 1926, **9**, 409–414.
35. Ewert, P. H., Bilateral Transfer in Mirror-Drawing. *Ped. Sem. and J. Gen. Psychol.*, 1926, **33**, 235–249.
36. Fildes, L. G., Experiments on the Problem of Mirror-Writing. *Brit. J. Psychol.*, 1923, **14**, 57–67.
37. Foucault, M., La persistance des aptitudes acquises. *L'Année Psychol.*, 1914–19, **21**, 110–118.
38. Frank, W., Über die Beeinflussung der geistigen und körperlichen Leistungsfähigkeit durch regelmässige Alkoholgaben. *Psychol. Arb.*, 1923–25, **8**, 22–47.
39. Freeland, G. E., A Year's Study of the Daily Learning of Six Children. *Ped. Sem.*, 1921, **28**, 97–115.
40. Freeland, G. E., Casual Practice Versus Practice Under Instruction. *J. Educ. Method*, 1924, **3**, 203–206.
41. Gates, A. I., The Abilities of an Expert Marksman Tested in the Psychological Laboratory. *J. Appl. Psychol.*, 1918, **2**, 1–14.
42. Gates, A. I., and Taylor, G. A., The Acquisition of Motor Control in Writing by Pre-School Children. *T. C. Record*, 1923, **24**, 459–468.
43. Gates, A. I., and Taylor, G. A., An Experimental Study of the Nature of Improvement Resulting from Practice in a Motor Function. *J. Educ. Psychol.*, 1926, **17**, 226–236.
44. Gates, G. S., The Meaning of the Term "Practice." *Psychol. Rev.*, 1922, **29**, 63–74.
45. Gates, G. S., Individual Differences as Affected by Practice. *Arch. of Psychol.*, 1922, **8**, No. 58. Pp. 74.
46. Gates, G. S., and Rissland, L. Q., The Effect of Encouragement and Discouragement Upon Performance. *J. Educ. Psychol.*, 1923, **14**, 21–26.
47. Gault, R. H., Progress in Experiments on Interpretation of Speech by Touch. *J. Abnorm. Psychol. and Soc. Psychol.*, 1925, **20**, 118–127.
48. Gault, R. H., Control Experiments in Relation to Identification of Speech Sounds by Aid of Tactual Cues. *J. Abnorm. Psychol. and Soc. Psychol.*, 1926, **21**, 4–13.
49. Gellhorn, E., Uebungsfähigkeit und Uebungsfestigkeit bei geistiger Arbeit. *Zsch. f. angew. Psychol.*, 1921, Beiheft 23. Pp. 77.
50. Gopalaswami, M., "Intelligence" in Motor Learning. *Brit. J. Psychol.*, 1924, **14**, 274–290.

51. GOPALASWAMI, M., Economy in Motor Learning. *Brit. J. Psychol.*, 1925, **15**, 226–236.
52. GOUGH, E., The Effects of Practice on Judgments of Absolute Pitch. *Arch. of Psychol.*, 1922, **7**, No. 47. Pp. 93.
53. GRAF, O., Über die Beeinflussung einfacher psychischer Vorgänge durch Cocain und Psicain. *Psychol. Arb.*, 1926, **9**, 244–273.
54. GRAY, C. T., A Comparison of Two Types of Learning by Means of a Substitution Test. *J. Educ. Psychol.*, 1918, **9**, 143–158.
55. GRÜNTHAL, E., Über den Einfluss der Willensspannung auf das fortlaufende Addieren. *Psychol. Arb.*, 1920–22, **7**, 483–534.
56. GYLYS, A., Die Beeinflussung der geistigen Arbeit durch verscheidene Konzentrationen von Alkohol. *Psychol. Arb.*, 1925, **9**, 157–194.
57. HANSEN, C. F., Serial Action as a Basic Measure of Motor Capacity. *Psychol. Monog.*, 1922, **31**, 320–382.
58. HAUGHT, B. F., The Interrelation of Some Higher Learning Processes. *Psychol. Monog.*, 1921, **30**, No. 139. Pp. 71.
59. HERON, W. T., and HUNTER, W. S., Studies in the Reliability of the Problem Box and the Maze With Human and Animal Subjects. II. Correlation Studies With the Maze in Rats and Humans. *Comp. Psychol. Monog.*, 1922, **1**, 37–56.
60. HERON, W. T., Individual Differences in Ability Versus Chance in the Learning of the Stylus Maze. *Comp. Psychol. Monog.*, 1924, **2**. Pp. 60.
61. HOKE, R. E., The Improvement of Speed and Accuracy in Typewriting. *Johns Hopkins Univ. Stud. in Educ.*, 1922, No. 7. Pp. 41.
62. HOLLINGWORTH, H. L., The Influence of Alcohol. *J. Abnorm. Psychol. and Soc. Psychol.*, 1923, **18**, 204–237.
63. HOLLINGWORTH, L. S., *Gifted Children*. N. Y.: Macmillan, 1926.
64. HULL, C. L., and HULL, B. I., Parallel Learning Curves of an Infant in Vocabulary and in Voluntary Control of the Bladder. *Ped. Sem.*, 1919, **26**, 272–283.
65. HUNTER, W. S., Habit Interference in the White Rat and in Human Subjects. *J. Comp. Psychol.*, 1922, **2**, 29–59.
66. HUNTER, W. S., and RANDOLPH, V., Further Studies on the Reliability of the Maze With Rats and Humans. *J. Comp. Psychol.*, 1924, **4**, 431–442.
67. HUNTER, W. S., A Reply to Professor Carr on "The Reliability of the Maze Experiment." *J. Comp. Psychol.*, 1926, **6**, 393–398.
68. ISRAEL, F., Ein neues Verfahren zur Messung der Geschicklichkeit. *Psychol. Arb.*, 1923–25, **8**, 115–128.
69. JOHNSON, B., Practice Effects in a Target Test—A Comparative Study of Groups Varying in Intelligence. *Psychol. Rev.*, 1919, **26**, 300–316.
70. JOHNSON, G. B., A Study in Learning to Walk the Tight Wire. *Ped. Sem. and J. Gen. Psychol.*, 1927, **34**, 118–128.
71. JOHNSON, O. J., A Study of the Relation Between Ability to Learn and Intelligence as Measured by Tests. *J. Educ. Psychol.*, 1923, **14**, 540–544.
72. KELLEY, C. M., and CARR, H. A., The Curve of Learning in Typesetting. *J. Exper. Psychol.*, 1924, **7**, 447–455.

73. KINCAID, M., A Study of Individual Differences in Learning. *Psychol. Rev.*, 1925, **32**, 34–53.
74. KITSON, H. D., A Study of the Output of Workers Under a Particular Wage Incentive. *Univ. J. Bus.*, 1922, **1**, 54–68.
75. KOCH, H. L., The Influence of Mechanical Guidance Upon Maze Learning. *Psychol. Monog.*, 1923, **32**, No. 147. Pp. 113.
76. KOCH, H. L., A Neglected Phase of the Part-Whole Problem. *J. Exper. Psychol.*, 1923, **6**, 366–376.
77. KOCH, H. L., and UFKESS, J., A Comparative Study of Stylus Maze Learning by Blind and Seeing Subjects. *J. Comp. Psychol.*, 1926, **9**, 118–131.
78. KOERTH, W., A Pursuit Apparatus: Eye-hand Coördination. *Psychol. Monog.*, 1922, **31**, 288–292.
79. KÜLZ, W. L., Wirkung von Arbeit und Alkohol auf die Geschicklichkeit. *Psychol. Arb.*, 1920–22, **7**, 464–482.
80. LANGE, J., Psychologisches Untersuchungen über die Wirkung von Kokain, Skopolamin und Morphin. *Psychol. Arb.*, 1920–22, **7**, 354–412.
81. LANGELÜDDEKE, A., Untersuchungen über die Vorgänge beim Erlernen des Maschineschreibens unter normalen und krankhaften Bedingungen. *Psychol. Arb.*, 1923–25, **8**, 304–413.
82. LAVÍN, C. R., A Preliminary Study of the Reproduction of Hand Movements. *Brit. J. Psychol.*, 1921, **12**, 47–52.
83. LIPMANN, O., Die psychische Eignung der Funkentelegraphisten. *Zsch. f. angew. Psychol.*, 1919, **15**, 301–340.
84. LUDGATE, K. E., The Effect of Manual Guidance Upon Maze Learning. *Psychol. Monog.*, 1923, **33**, No. 148. Pp. 65.
85. MATHER, J. E., and KLINE, L. W., The Psychology of Solving Puzzle Problems. *Ped. Sem.*, 1922, **29**, 269–282.
86. MCCLATCHY, V. R., The Optimal Position of a Rest Period in Learning. *J. Exper. Psychol.*, 1925, **8**, 251–277.
87. MEYER, M. F., and EPPRIGHT, F. O., The Equation of the Learning Function. *Amer. J. Psychol.*, 1923, **34**, 203–222.
88. MEYER, M. F., Alcohol, Tobacco and Tea: the Efficiency Under Drugs as Derived From the Learning Equation. *Amer. J. Psychol.*, 1923, **34**, 501–510.
89. MICHAELIS, A., Der Bourdon-Test bei 12 jährigen Schülern. *Zsch. f. päd. Psychol.*, 1922, **23**, 258–268.
90. MYERS, G. C., Some Variabilities and Correlations in Learning. *Amer. J. Psychol.*, 1918, **29**, 316–326.
91. NOBLE, S. G., The Acquisition of Skill in Throwing Basket-ball Goals. *Sch. and Soc.*, 1922, **16**, 640–644.
92. NORCROSS, W. H., Experiments on the Transfer of Training. *J. Comp. Psychol.*, 1921, **1**, 317–363.
93. PEAR, T. H., *Skill in Work and Play.* N. Y.: Dutton, 1924.
94. PEAR, T. H., Skill. *J. Personnel Res.*, 1927, **5**, 478–489.
95. PECHSTEIN, L. A., Whole vs. Part Methods in Motor Learning. A Comparative Study. *Psychol. Monog.*, 1917, **23**, No. 99. Pp. 80.
96. PECHSTEIN, L. A., Alleged Elements of Waste in Learning a Motor Problem by the "Part" Method. *J. Educ. Psychol.*, 1917, **8**, 303–310.

97. PECHSTEIN, L. A., Massed vs. Distributed Effort in Learning. *J. Educ. Psychol.*, 1921, **12**, 92–97.
98. PERRIN, F. A. C., The Learning Curves of the Analogies and the Mirror Reading Tests. *Psychol. Rev.*, 1919, **26**, 42–62.
99. PETERSON, J. C., The Higher Mental Processes in Learning. *Psychol. Monog.*, 1920, **28**, No. 129. Pp. 121.
100. PETERSON, J., Experiments in Ball-Tossing: The Significance of Learning Curves. *J. Exper. Psychol.*, 1917, **2**, 178–224.
101. PETERSON, J., Thurstone's Measures of Variability in Learning. *Psychol. Bull.*, 1918, **15**, 452–456.
102. PETERSON, J., Experiments in Rational Learning. *Psychol. Rev.*, 1918, **25**, 443–467.
103. PETERSON, J., Tentative Norms in the Rational Learning Test. *J. Appl. Psychol.*, 1920, **4**, 250–257.
104. PETERSON, J., The Rational Learning Test Applied to Eighty-one College Students. *J. Educ. Psychol.*, 1920, **11**, 137–150.
105. PETERSON, J., The Backward Elimination of Errors in Mental Maze Learning. *J. Exper. Psychol.*, 1920, **3**, 257–280.
106. PETERSON, J., Learning When Frequency and Recency Factors Are Negative. *J. Exper. Psychol.*, 1922, **5**, 270–300.
107. PETERSON, J., Johnson's Measurement of Rate of Improvement Under Practice. *J. Educ. Psychol.*, 1924, **15**, 271–275.
108. PETERSON, J., Limits of Learning by Trial and Error. *J. Exper. Psychol.*, 1926, **9**, 45–55.
109. PETERSON, J., LANIER, L. H., and WALKER, H. M., Comparisons of White and Negro Children in Certain Ingenuity and Speed Tests. *J. Comp. Psychol.*, 1925, **5**, 271–283.
110. PHILLIPS, F. M., Relation of Initial Ability to the Extent of Improvement in Certain Mathematical Traits. *Ped. Sem.*, 1919, **26**, 330–355.
111. PYLE, W. H., Is Individual Learning Capacity Constant for Different Types of Material? *J. Educ. Psychol.*, 1919, **10**, 121–128.
112. PYLE, W. H., Transfer and Interference in Card-distributing. *J. Educ. Psychol.*, 1919, **10**, 107–110.
113. PYLE, W. H., *The Psychology of Learning.* Baltimore: Warwick and York, 1921.
114. PYLE, W. H., Sex Differences and Sex Variability in Learning Capacity. *Sch. and Soc.*, 1924, **19**, 352.
115. PYLE, W. H., *Nature and Development of Learning Capacity.* Baltimore: Warwick and York, 1925.
116. RACE, H. V., Improvability: Its Intercorrelations and Its Relations to Initial Ability. *T. C. Contr. to Educ.*, 1922, No. 124. Pp. 68.
117. REAM, M. J., The Tapping Test: A Measure of Motility. *Psychol. Monog.*, 1922, **31**, 293–319.
118. REED, H. B., The Effect of Training on Individual Differences. *J. Exper. Psychol.*, 1924, **7**, 186–200.
119. REED, H. B., Distributed Practice in Addition. *J. Educ. Psychol.*, 1924, **15**, 248–249.
120. REXROAD, C. N., Administering Electric Shock for Inaccuracy in Continuous Multiple Choice Reactions. *J. Exper. Psychol.*, 1926, **9**, 1–18.

121. REXROAD, C. N., Verbalization in Multiple Choice Reactions. *Psychol. Rev.*, 1926, **33**, 451–458.
122. RIEGEL, A., Über Gewöhnung an Alkohol. *Psychol. Arb.*, 1923–25, **8**, 48–71.
123. ROOT, W. T., A Socio-Psychological Study of Fifty-three Supernormal Children. *Psychol. Monog.*, 1921, **29**, No. 133. Pp. 134.
124. RUCH, G. M., Correlations of Initial and Final Capacities in Learning. *J. Exper. Psychol.*, 1923, **6**, 344–356.
125. RUCH, G. M., The Influence of the Factor of Intelligence on the Form of the Learning Curve. *Psychol. Monog.*, 1925, **34**, No. 160. Pp. 64.
126. SCHRIEVER, H., Untersuchungen über den Einfluss der Wiederholung und Übung auf Testleistung. *Arch. f. d. ges. Psychol.*, 1924, **49**, 283–310.
127. SMITH, M., and MCDOUGALL, W., Some Experiments in Learning and Retention. *Brit. J. Psychol.*, 1920, **10**, 199–209.
128. SNODDY, G. S., An Experimental Analysis of a Case of Trial and Error Learning in the Human Subject. *Psychol. Monog.*, 1920, **28**, No. 124. Pp. 78.
129. SNODDY, G. S., Learning and Stability. A Psychophysiological Analysis of a Case of Motor Learning with Clinical Applications. *J. Appl. Psychol.*, 1926, **10**, 1–36.
130. SPENCER, L. T., The Effects of Practice Without Knowledge of Results. *Amer. J. Psychol.*, 1923, **34**, 107–111.
131. STICKLAND, G. I., The Influence of Practice on the Correlation of Abilities. *J. Educ. Psychol.*, 1918, **9**, 393–399.
132. STODDARD, G. D., The Problem of Individual Differences in Learning. *Psychol. Rev.*, 1925, **32**, 479–485.
133. STURT, M., A Comparison of Speed With Accuracy in the Learning Process. *Brit. J. Psychol.*, 1921, **12**, 289–300.
134. SWIFT, E. J., Review of Book's *Learning to Typewrite*. *Sch. and Soc.*, 1926, **23**, 372–373.
135. THORNDIKE, E. L., The Influence of the Chance Imperfections of Measures Upon the Relation of Initial Score to Gain or Loss. *J. Exper. Psychol.*, 1924, **7**, 225–232.
136. THORNDIKE, E. L., The Influence of Primacy. *J. Exper. Psychol.*, 1927, **10**, 18–29.
137. THURSTONE, L. L., Variability in Learning. *Psychol. Bull.*, 1918, **15**, 210–212.
138. THURSTONE, L. L., Three Methods of Teaching Radio Telegraphy. *J. Educ. Psychol.*, 1918, **9**, 467–470.
139. THURSTONE, L. L., The Learning Curve Equation. *Psychol. Monog.*, 1919, **26**, No. 114. Pp. 51.
140. TOWNE, B. M., An Individual Curve of Learning: A Study in Typewriting. *J. Exper. Psychol.*, 1922, **5**, 79–92.
141. TROW, W. C., and SEARS, R., A Learning Plateau Due to Conflicting Methods of Practice. *J. Educ. Psychol.*, 1927, **18**, 43–47.
142. TSAI, C., A Comparative Study of Retention Curves for Motor Habits. *Comp. Psychol. Monog.*, 1924, **2**. Pp. 29.
143. WANG, T. L., The Influence of Tuition in the Acquisition of Skill. *Psychol. Monog.*, 1925, **34**, No. 154. Pp. 51.

144. WARDEN, C. J., Primacy and Recency as Factors in Cul-de-sac Elimination in a Stylus Maze. *J. Exper. Psychol.*, 1924, **7**, 98–116.
145. WARDEN, C. J., The Relative Economy of Various Modes of Attack in the Mastery of a Stylus Maze. *J. Exper. Psychol.*, 1924, **7**, 243–275.
146. WARDEN, C. J., Judgments of Certain Space Relations Based Upon the Learning of a Stylus Maze. *J. Exper. Psychol.*, 1925, **8**, 399–407.
147. WEBB, L. W., Transfer of Training and Retroaction. *Psychol. Monog.*, 1917, **24**, No. 104. Pp. 90.
148. WEGER, H., Über Geschicklichkeitsmessungen. *Psychol. Arb.*, 1920–22, **7**, 442–463.
149. WEMBRIDGE, E. R., and GABEL, P., Multiple Choice Experiment Applied to School Children. *Psychol. Rev.*, 1919, **26**, 294–299.
150. WOODROW, H., Practice and Transference in Normal and Feeble-Minded Children. *J. Educ. Psychol.* 1917, **8**, 85–96, 151–165.
151. WOOSTER, M., Certain Factors in the Development of a New Spatial Coördination. *Psychol. Monog.*, 1923, **32**, No. 146. Pp. 96.
152. WYATT, S., and WESTON, H. C., A Performance Test Under Industrial Conditions. *Brit. J. Psychol.*, 1920, **10**, 291–309.
153. ZECH, J., Über den Einfluss kleiner Nahrungsmengen auf die geistige Lesitungsfähigkeit. *Psychol. Arb.*, 1925, **9**, 195–210.

THE CURVE OF CONTINUOUS WORK AND RELATED PHENOMENA[1]

BY LLEWELLYN T. SPENCER

Yale University

Investigations of the characteristics of the curve of continuous work have shown a striking shift of emphasis in the last six years. The last review [2] of this field reported numerous investigations and critical discussions of initial spurt, warming-up, general decrement, and end spurt. Of late, however, the emphasis has been mainly on the phenomenon of the general decrement, and in particular upon the practical problems of fatigue. Only a few investigations are concerned with other elements of the curve. Reed (22) found that in a 10-hour period of continuous mental work (addition) there was no observable initial spurt, end spurt, warming up, or decrement, when time was called every minute during the first 15 and the last 10 minutes and every 10 minutes during the intervening period. Evidence for an initial spurt was found by Morgan (18) when measures were taken at one-half minute intervals but very little further decrement after the first 12 minutes of work (cancellation or addition). Robinson and Heron (25) reported evidence for a warming-up effect in tapping and backward recitation of the alphabet, which they felt was distinct from the improvement directly due to general exercise of the functions.

The importance of the so-called monotony factor of the general decrement, especially for simple tasks, has been clearly demonstrated by Robinson and Bills (24). A number of simple functions such as writing various letter combinations and the naming of letters can be arranged in a fairly objective order according to the degree of homogeneity. The degree of homogeneity was shown to have a direct relation to the amount of the general decrement shown in continuous exercise of the functions. Mere homogeneity as such is not independently effective, according to Winkler (29). He notes individual differences in susceptibility to the monotony of such work and concludes that the decrement is influenced by the degree to which an

[1] This review covers the period from 1921 to the end of 1926.

[2] ROBINSON, E. S., PSYCH. BULL., 1921, 18, 456-482.

individual is able to escape from the work by turning his attention elsewhere. Where attention is required in the task, as in reaction time measurements, Wells, Kelley, and Murphy (28) find that repeated observations produce a gradual increase in the simple reaction time, which simulates a fatigue effect. Since the actual amount of muscular fatigue is certainly slight in this situation, the considerable loss in efficiency is clearly due to the monotony or "sporific" effect of the task.

Robinson (23) suggests that certain principles may be generalized from what is known with regard to the general decrement. He points out that the decrement is in all probability the result of a complex of conditions. Accordingly he lays down seven principles which hold both for speed and accuracy in the performance of a function. The decrement occurring in the exercise of a function is relative to (1) the recency of the previous functioning of that S-R connection, (2) the frequency of the previous functioning, (3) the connections existing between the S and other R's, (4) the strength of the S-R connection, (5) the qualitative integrity of the S during the period of exercise, (6) the quantitative integrity of the S, and (7) the decrements that have developed in other S-R connections. The greatest decrement would therefore presumably occur when a stimulus-response connection was frequently and consecutively exercised, where it was subject to considerable competition because of the connection of other responses with the stimulus in question and was especially susceptible to such interference because of inadequate strength of connection, and particularly where the stimulus remained qualitatively and quantitatively the same throughout the working period. Greater decrement is to be expected when other S-R connections are exhibiting decrement, through some as yet unclarified process of transfer. Such transfer, for example, is reported by Apajalahti and Panelius (1) who found that slight bodily work (ergograph) decreases precise adjustment work (needle-threading) 2 per cent and relatively heavy body work (wood-sawing) decreases the precision work from 9 per cent to 14 per cent. Dockeray (6) reports a decrease in attentive coördination measured by a special apparatus after mental (arithmetic) work.

Individual variation in the characteristics of the work curve offers a field for further investigation. More information is needed according to Florence (8) on the reasons which lead to an individual work curve and also as to means of interpreting individual variations from the typical curve. Florence found that a squad of individuals

tends to approximate a single type of curve and feels that much of practical value may be gained from an analysis of individual variants. Wunderlich (31) distinguishes three different kinds of work corresponding to three different kinds of workers: (1) that requiring complete attention—which produces monotony; (2) that which can be done with divided or alternating attention; and (3) that which can be done quite mechanically, *i.e.*, that which permits of independent thinking. Workers gravitate toward the type of work which best suits their personalities or are molded into such personalities by the type of their work. Szymanski (27) distinguishes two types of worker, the intermittent and the continuous. The latter are characterized by inner drives. Fluctuations in the course of the curve of work are found to be less for individuals with cerebral injuries, in the groups studied by Langelüddeke (14) although the general level of efficiency is lower. This regularity of output he attributes to more even volition and attention. These various distinctions make it clear that the individual curve of work is a function of variation in the type of task and also in the type of the worker.

Difficulties in interpreting the values expressed in the curve of work are pointed out by Poppelreuter and by Farmer. Poppelreuter (20) stresses the incomparability of fatigue curves obtained in the laboratory with similar curves obtained in practical work. Spontaneous rest pauses occur in practical work and the decrement may be largely eliminated. A further distinction, offered by Farmer (7) is that practical work activities are habituated and maximal effort is not the important factor. Changes in the conditions and methods of industrial work may affect the output in several ways; not all improvements produced by the psychologist result in the same sort of modification. Changes may result in a curve of the same form but on a higher level; this shows that speedier work has been made possible and perhaps involves less effort per unit of output. Again the output level may be the same but the decrement be diminished. Further a higher level may be produced but with more rapid decrement or a higher level with a diminished decrement. The last represents the most improvement by the changes but the other effects may each be valuable increments either in the output or in the ease of the work. Farmer also argues for a more uniform system of reporting work curves. He suggests that the average time taken per unit of output for the full work period be set equal to 100, and scores for each period be expressed in percentages of this value. Then improved output would be indicated by values less than 100

and poorer output by values greater than 100. Thus curves from all sorts of industrial situations might be sent in to a central office for study and a much more general insight into the conditions and factors producing the decrement might be gained. This type of attack also has the advantage of working with actual conditions, where habits and motivation are already largely adjusted to real situations, so that any aid the psychologist might give would be a practical relief to the worker.

Considerable interest has attached recently to objective measures of fatigue as produced either by physical work or by mental work. Nuttal (19) in a summary of fatigue and its problems stresses the work of Bose who has shown a similar fatigue and recuperation for animals, plants, and metals and who explains the phenomena as due to a molecular change and recovery, rejecting the theory of a fatigue toxin. Lee and Aronovitch (16) in criticism of Weichardt's supposed fatigue toxin cite an experiment in which juices squeezed from fatigued muscles of cats and injected into guinea pigs produced effects identical with those given by juices from unfatigued muscle. Lee (15) further reports the same results when guinea pigs are used in all parts of the experiment. Arborelius and Leljestrand (2) find differences in the H ion concentration of the blood after muscular work of different degrees. Johnson (12) reports increases in blood sugar content after simple muscular and, frequently, after light mental work (discrimination and substitution tests). Muscular work is associated with an increase in the action current, according to Cobb and Forbes (4) but there is a decrease in the frequency of the current. This they suggest is due either to a block in the neuromuscular junction or to a decrease in the irritability of the muscle. Lee and Vanbuskirk (17) conclude that cardiovascular, respiratory efficiency, and resistance strength tests are invalid in measuring physical fatigue.

Knipping (13) finds the measurement of phosphoric acid in the blood a more satisfactory measure of mental work than respiration calorimetry. The effects of mental work on physiological functions are summarized by Poyer (21) and include changes in the circulation, heart beat, and blood pressure, an increase in the rate of respiration and a decrease in amplitude, a slight increase in body temperature, and a reduction of the resistance to physical fatigue. He questions the diminution of tactile sensitivity sometimes reported after mental work, but accepts hyperalgesia. Considerable contradiction seems to occur in the findings of various investigators with regard to these

effects. Ilzhoefer (11) reports increases in the rate, volume, and depth of breathing but feels actual increases in the expenditure of energy in mental work are principally due to manifold muscular tensions which are irrelevant to the mental work. Chlopin (3) obtained similar results and makes the same reservation as to the processes conditioning the changes. Blood pressure and pulse rate are increased in mental work in the experiments of Day (5) and of Gillespie (10). Gellhorn (9), however, finds a lowering of the pulse and also of the body temperature by both mental and physical work; the pulse being more affected in mental work and the temperature more in physical. Chlopin points out that there are individual exceptions to most of the generalizations. Toward the end of a university semester Wolf (30) finds a fatigue effect as measured by tests of cancellation, proof-reading, recognition memory, and aesthesiometer readings, but all physiological criteria fail to show clear evidence of fatigue.

By far the most prolific literature in the field of fatigue and its related problems is published by the practical investigators of the so-called Arbeitspsychologie group. Investigations range from a study of particular optima for a given industrial task to the establishment of restitution constants from which the length of the optimal rest periods may be calculated for the individual, independent of the amount of energy expended per unit task (Simonson, 26). A summary of these investigations would be material for an independent review, and for the general purpose of this paper would include little of abstract interest. It is not difficult, however, to see in this practical interest the explanation for the present dearth of experimental investigations of the curve of continuous work as a general phenomenon.

REFERENCES

1. Apajalahti, A., and Panelius, A., *Skand. Arch. f. Physiol.*, 1921, **41**, 195–199.
2. Arborelius, M., and Leljestrand, G., *Skand. Arch. f. Physiol.*, 1923, **44**, 215–236.
3. Chlopin, G. W., and Okunewsky, J. L., *Archiv f. Hygiene*, 1922, **91**, 317–331.
4. Cobb, S., and Forbes, A., *J. of Nerv. and Ment. Dis.*, 1923, **58**, 273–274.
5. Day, M. E., *J. of Comp. Psychol.*, 1923, **3**, 333–377.
6. Dockeray, F. C., *J. of Comp. Psychol.*, 1922, **2**, 331–370.
7. Farmer, E., *Brit. J. of Psychol., Gen. Sec.*, 1923, **13**, 308–314.
8. Florence, P. S., *Rep. Brit. Assn. Adv. Sci.*, 1923, 461.
9. Gellhorn, E., *Pflügers Archiv f. d. ges. Physiol.*, 1921, **189**, 144–180.

10. GILLESPIE, R. D., *J. of Physiol.*, 1924, **58**, 425–432.
11. ILZHOEFER, H., *Arch. f. Hygiene*, 1924, **94**, 317–328.
12. JOHNSON, B., *J. of Comp. Psychol.*, 1922, **2**, 155–171.
13. KNIPPING, H. W., *Z. f. Biol.*, 1923, **77**, 165–174.
14. LANGELÜDDEKE, A., *Z. f. d. ges. Neur. u. Psychol.*, 1920, **58**, 216–265.
15. LEE, F. S., *Am. J. of Physiol.*, 1924, **69**, 101–106.
16. LEE, F. S., and ARONOVITCH, B., *Am. J. of Physiol.*, 1924, **69**, 92–100.
17. LEE, F. S., and VANBUSKIRK, J. D., *Am. J. of Physiol.*, 1923, 185–206.
18. MORGAN, L. T., *Am. J. of Psychol.*, 1926, **37**, 402–407.
19. NUTTAL, G. C., *Contemp. Rev.*, 1922, **122**, 212–218.
20. POPPELREUTER, W., *Prakt. Psychol.*, 1923, **4**, 363–383.
21. POYER, G., *J. de Psychol.*, 1921, **18**, 300–319.
22. REED, H. B., *J. of Educ. Psychol.*, 1924, **15**, 389–392.
23. ROBINSON, E. S., *Psychol. Rev.*, 1926, **33**, 123–134.
24. ROBINSON, E. S., and BILLS, A. G., *J. of Exper. Psychol.*, 1926, **9**, 415–443.
25. ROBINSON, E. S., and HERON, W. T., *J. of Exper. Psychol.*, 1924, **7**, 81–97.
26. SIMONSON, E., *Pflügers Archiv f. d. ges. Physiol.*, 1927, **215**, 716–742.
27. SZYMANSKI, J. S., *Zeitschr. f. angew. Psychol.*, 1921, **18**, 1–18.
28. WELLS, F. L., KELLEY, C. M., and MURPHY, G., *J. of Exper. Psychol.*, 1921, **4**, 137–142.
29. WINKLER, H., *Zeitschr. f. angew. Psychol.*, 1922, **20**, 46–88.
30. WOLF, F., *Arch. f. Hygiene*, 1922, **91**, 99–142.
31. WUNDERLICH, H., *Zeitschr. f. angew. Psychol.*, 1925, **25**, 321–373.

The following articles were inaccessible to the reviewer but are listed in the Psychological Index:

Effects of Mental Work

DE SANCTIS, S., La curva del lavoro mentale. *Riv. di Biol.*, 1924, **6**, 210–227.

RITCHIE, F. M., Some effects of prolonged, unvaried mental work. *For. Educ.*, 1924, **2**, 48–61; 83–98.

TOULOUSE, E., and TARGOWLA, —., Note sur les modifications artérieles de l'effort mental. *Bull. Soc. clin. méd. ment.*, 1921, 33–40.

BARTSCH, M., Uber den Einfluss von körperlicher Arbeit auf die Blutzusammensetzung. *Beitr. z. Physiol.*, 1923, **2**, 79–82.

Effects of Muscular Work

FLOCKENHAUS, M., Geistige Leitungsfähigkeit nach schwere körperlicher Anstrengung. *Med. Klinik*, 1923, **19**, 574–575.

MACKEITH, N. W., ET AL., Observations on the adjustment of the human body to muscular work. *Proc. Roy. Soc. Lon.*, A, 1923, **95**, 413–439.

TERASAWA, B. I., Transfer of Fatigue. *Jap. J. of Psychol.*, 1923, 1, 77–144.

INHIBITION AND FACILITATION

BY A. G. BILLS
The University of Chicago

I. The Nature of the Processes.

The terms " inhibition " and " facilitation " have both a technical and a general meaning in psychology. According to the general signification, all factors, internal or environmental, tending to influence favorably or unfavorably the efficiency of mental work could be termed facilitators and inhibitors respectively. This nontechnical usage will be understood to apply in the present review.

On the other hand, a more technical analysis in physiological terms has been attempted in the recent papers of Dodge (**9**). He there raises the question whether any satisfactory explanation has yet been given for either process, or whether that which the physiologist means by neural inhibition has any real relation to mental phenomena. Facilitation, or the increase of neural action by increased stimulation, he considers axiomatic; but a decreased neural action from increased stimulation needs explanation. Among the different types of inhibition he recognizes (1) the mechanical type exercised by antagonistic muscles, or " terminal " inhibition, (2) reflex inhibition, as is met with in the knee jerk when the second blow falls within the relative refractory phase created by the first, and (3) central inhibition, such as the deadening of the knee jerk upon relaxation of the thigh muscles.

Again, inhibition may be due to rivalry of impulses and competition for a final common path, as for example in Dodge's (**10**) post-rotation nystagmus experiment, where the vestibular reflex is inhibited by the opposing visual stimuli. In the field of sensation, a stronger stimulus can render a weaker one subthreshold, as was recently demonstrated by Spencer (**46**) who got inhibitory effects upon the threshold stimulation of one retina, by simultaneously stimulating the other. Kline (**28**) showed that certain persistent sets, prejudices, or associative bonds may cause inhibition of subsequent excitations.

Finally, there is that form of central inhibition, analogous to learning and adaptation, by which excitability is gradually diminished

over a period of repeated stimulation. Dodge (11) got inhibition of after-nystagmus after a long series of rotation experiments.

The two most prominent present day theories of neural inhibition are the drainage theory, favored by McDougall (35), and the refractory phase hypothesis of Verworn, favored by Dodge (12). The former theory assumes that the activity of any neural system involving higher level arcs tends to inhibit all other systems by draining off their energy. Dodge objects to this because it assumes a flow of nervous energy, an unjustified assumption, in view of the discrepancies in energy at different stages of the arc. It also violates the " all or none " principle. He denies, also, that decrement of a reflex regularly occurs as a correlate of increased spread of neural excitation, since, in his experiments, he got no inhibition of the patellar or lid reflexes as a result of voluntary spread of excitation. McDougal (35), however, replies that the drainage theory does not call for an invariable inhibitory effect of increased spread of excitation. It is safe to say, though, that even though the drainage theory does offer a facile explanation of certain phenomena, its dependence on an exploded concept of " neurin " makes it untenable.

The other hypothesis, that of refractory phase, assumes a period of decreased excitability subsequent to stimulation. It is called absolute when the reëxcitation of tissue is not possible by maximal stimuli. Otherwise it is relative refractory phase. Its obvious contradiction of the all or nothing law is not serious, since that law does not preclude changes in the maximal capacity of an arc from time to time.

The concept is doubtless an important one in mental work, since it probably accounts for the inhibitory effect of work upon itself. However, the inhibition caused by competing impulses seems to need further explanation. And the inhibition and facilitation involved in the action of permanent " sets " or attitudes, a type to which we will frequently refer, apparently belongs to a different classification. Myers (40) attacks this distinction in his discussion of fatigue and adaptation, in which he distinguishes between the lessened functional activity characteristic of refractoriness, and the new functional activity involved in adaptation, and in those relatively enduring sets or attitudes of the organism.

The question of the nature of facilitation has caused less speculation, probably because it agrees better with the general notion of mechanical acction. Herrick (21) mentions several closely related modes of facilitation for the explanation of which he invokes synaptic

mechanisms. Thus there may be (1) diffusion of excitation, (2) summation of nervous impulses in a final common path, so that even subliminal stimuli reinforce the ultimate response, (3) the so-called avalanche conduction, where a single stimulation leads to a diffuse excitation which in turn is united in an augmented final common path, (4) the integration of diverse sense modalities, so that totally dissimilar impulses may reinforce each other, and finally (5) the more labile processes of correlation and association in general. We might add that permanent facilitating attitudes or "sets" are conceivable just as are inhibiting "sets."

II. Classification of Facilitators and Inhibitors.

While the theoretical question is engaging speculative thought, the experimental literature bearing upon the facilitating and inhibiting effects of various specific environmental factors continues to accumulate. In general there has been a shift in interest away from the grosser physiological factors to the more subtle and complex mental influences. Such a shift carries with it the danger of a less rigid experimental technique, with looser definition of the variables involved. Thus a factor like tobacco is a much more tangible variable to control than one like "mood" or "set" or "incentive." Yet studies like those of Hull (**22**) show that even as simple a variable as the presence or absence of tobacco may be complicated by subtler influences, as suggestion.

It is not feasible to attempt to classify facilitators and inhibitors separately, for the same factor may exert a directly contrary influence under slightly changed conditions. A quantitative or qualitative change in the variable may alter it from a facilitator to an inhibitor or vice versa. Hence each factor must be considered from both angles.

Certain large classes of factors may be set aside at once. Thus all agents of a plainly physiological type as drugs, food, oxygen supply, etc., have been discussed elsewhere. The same is true of those factors involved in the influence of work upon itself, as shown in the curve of continuous work. This narrows the field down to a discussion of those extrinsic influences either in the individual's psychic environment or in his own mental attitude, which exert an influence on his efficiency in performing mental tasks.

A. Background

A considerable group of facilitating and inhibiting influences fall under the general heading of *background*. The appreciable effect of such factors argues for the truth of the Configurationist's doctrine that man reacts only to the total situation or "Gestalt," rather than to isolated stimuli.

The visual background should be extremely important, yet experimental work on problems such as color of walls, view from windows, color of light, mural pictures, etc., is left unexplored even by industrial psychologists, with rare exceptions. Pressey (42) experimented with various shades of illumination, and found no appreciable differences for different colors, but did get better results with more intense degrees of illumination. Since that time, the subject of intensity has been widely studied. Atkins (1) has recently reviewed this literature. All results point to increased efficiency with increased illumination up to 20 F.C. A different problem, the relation of brightness of background to that of field, for optimal results, was investigated independently by Atkins (1), and Johnson (26). Atkins found that a brightness of 37 ml. gave greatest efficiency with black surroundings, whereas with white surroundings, only the lowest brightness was comfortable, yet all intensities gave equal efficiency. Johnson showed that the best ratio between brightness of surroundings and that of field is .74, where the field is slightly less, and any increase in the ratio causes a rapid loss of efficiency.

Another phase of the problem of background relates to atmospheric conditions insofar as these are not treated from a purely physiological angle. Bethel (2) reports a study of the effects of weather conditions on short periods of mental work. Two kinds of tests were given to five subjects; a test of visual memory, the immediate and delayed recall of nonsense syllables; and a test of auditory memory, the immediate recall of numbers. The tests were given weekly, over a period of four months. The visual results were somewhat baffling, since three cases show little or no relation between efficiency of immediate recall and humidity, whereas one shows direct variation between the two, and two show perfect inverse variation. In general weather influences auditory more than visual memory, showing marked effects upon the former. Relative humidity, barometric pressure and temperature appear to affect efficiency inversely, *i.e.*, as humidity, pressure, and temperature rise, the scores for auditory memory become lower. The results indicate that baro-

metric pressure is the most important factor. A low pressure is favorable to mental work. The author suggests what is most probable, that the subject's affective state at the time has a lot to do with it, and no doubt his affective state is the outcome of atmospheric conditions in large part. For Sullivan (**47**), in studying the effect of mood on performance, incidentally investigated the relation between mood and the weather conditions prevailing at the time. The subjects rated themselves on a graphic scale as to mood at the beginning of each experiment; writing, in addition, a short description of their mood, which was later evaluated by six judges. Weather conditions were regularly recorded. A definite relation between mood and the weather was discovered, a cheerful mood tending to prevail on bright, pleasant days, and various degrees of depression on gloomy, disagreeable days. Yet a very low correlation was found to obtain between mood and performance in mental work, such as drawing lines equal to a remembered standard, addition, color naming, and free association.

Time of year may affect efficiency. Thus Vernon (**53**), experimenting with workers in a rolling mill found that their relative output was, in the winter 102–124, in the autumn 98–118, and in the summer 88–111. A mean weekly temperature of 40–45 degrees gave 102, whereas one of 60–65 gave 93. Weston (**54**) found a rise and fall of roughly 1 per cent in efficiency for each degree rise or fall in wet bulb temperature, in the linen weaving industry.

A phase of background worthy of consideration is that of the simultaneous stimulation of other senses than those employed in the particular task being performed. Thus music and accompanying rhythms form an important factor. Diserens (**7**) has recently reviewed the field of music as it influences human behavior. Among the many experiments quoted by him, a striking one is that of Smith (**45**), who tried playing phonograph music during sorting hours in the Minneapolis post office with the result that errors in sorting were reduced about 13 per cent. The conclusions which Diserens draws from the experimental literature are that music increases body metabolism, lowers the threshold for sensory stimuli, and affords the physiological basis for genesis of emotions with their energizing effect on reactions. In an experiment of his own, Diserens investigated the effect of phonograph music, slow and fast, on the onset of fatigue, on the speed, accuracy, and extent of voluntary movement, and on some vital functions. The results show considerable contradiction. Thus fatigue from continuous dynamometer

squeezing was delayed, but not the fatigue from intermittent ergographic work, the rhythm of the music seeming to interfere. Accuracy in typing and handwriting from copy was decreased, but speed was increased. The extent of voluntary movements was increased, and breathing became deeper. His pressure records in writing point to an increase in muscular tension under music, whereas the galvanometer readings are interpreted by the author to mean a relaxing of muscle tonus. Probably the safest general statement from the results would be that music is shown to be a mild energizer.

Gatewood (19) investigated the influence of music on the efficiency of draughtsmen in an architectural drafting room. Their work consisted of completing plans. She used 56 subjects, who were later questioned for the effects of the music on their work, the preferred type of music, the probable manner in which it exerted its effects, and the optimal distribution of music and silence. Forty-nine reported a beneficial effect, and only six were distracted. Jazz and familiar music were preferred. The majority attributed the benefit to the fact that it kept them happy, though some thought it energized them directly, and others that it furnished rest intervals. The majority preferred music all the time. Aside from the fact that questionnaires are always inaccurate and subjective, the results are suggestive. Gilliland and Moore (20), reporting a study on the immediate and long-time effects of classical and popular selections, find some tendency toward an energizing effect of jazz music as compared to classical music on speed of tapping. Hyde (24) studied the effects of music on electrocardiograms and blood pressure, thus throwing light indirectly on the problem. She chose as subjects, (1) persons fond of music, (2) those indifferent to it, (3) some Indians, (4) neurasthenics, and (5) animals. In general, it made a difference whether the music was familiar or not, and whether sung or played. Persons not susceptible to music were unaffected, and the Indians responded only to the war dance. But those who were susceptible got a lowering of functions from Tchaikowski, but a raised tonus from the Toreador song, and the national emblem march. Lullaby records were soothing.

Many investigators are of the opinion that music exerts its influence through its directive effect on work rhythms. That work with rhythm is more efficient than work without any rhythm is well recognized. Ermanski (14), discussing the subject, declares that rhythm furnishes the basis for a rational organization of work. It saves by equalizing the work units; a rapid automatization follows

rhythmic work due to elimination of interfering tendencies. Effort is equalized and controlled, and the separate part processes are reinforced thereby. Farmer (15), in a study on spoon polishing has shown that when fatigue breaks down the work rhythms in industry, there is less accuracy and a greater expenditure of energy to secure the same output. Though some of the benefits of music can be accounted for in this way, there is doubtless also a dynamogenic effect of tone stimuli themselves.

Extraneous stimuli acting upon the mental worker may, however, exert a detrimental influence on efficiency, and such factors are properly called distractions. Yet occasionally so-called distractors act paradoxically and aid efficiency. Dockeray (8) investigated the effect of various forms of distraction on a continuous discriminatory reaction to sounders. His distractors were of two kinds, one the continuous ringing of an electric buzzer, and the other a weak induction shock applied to the left forearm. The mental work involved discriminating between four sounders, tuned to slightly different pitch, sounded in irregular order, one every second. To increase the difficulty of discrimination, a fifth note was sounded with the other four. A normal and distracted series of twenty minutes were run each day. The six subjects reacted by pressing a key to the specified sound. By dividing the total per cent of failures under distraction by that under normal, a ratio was found. If this was above 100, it meant that the subject made a poorer showing under distraction than under normal. The results show no constant tendency. Two subjects show ratios of 103, or practical equality; one excels under distraction; two under normal; while one excels under distraction in one series and under normal in the other. The results seem to agree with previous findings, that the effect of distractors is equivocal, sometimes reinforcing and sometimes inhibiting the activity engaged in.

Tinker (48), desiring to find out whether intelligence test scores show any correlation with the distractibility of the subject tested, tried to devise a measure of distractibility. The subjects were given a stylus maze to learn. Whenever they made contact with the sides of the maze paths, a bell rang, thus furnishing distraction. He found that the supposed distraction merely decreased the speed and increased the accuracy of motor performance. It evidently acted as a mild punishment for wrong moves, putting a premium on cautious slow movement. Very low correlations obtained between amount of change under distraction and performance in intelligence tests.

Whether the same results would have shown had the distractions been introduced directly into the intelligence test situation remains to be investigated.

Laird (34) refers briefly to a six months' experiment in which the cost of auditory distractions in industry was studied. When the usual office noises were quieted with wall panels of acousti-celotex, the experimenters, Harford and Turino, found that output of typists was increased 4.3 per cent, with approximately one fourth less energy expenditure. The author fails to state how energy expenditure was measured; hence no inferences are justified from this. No doubt the intermittent, unexpected and often attention-compelling distraction of human voices acts differently from the impersonal types of the laboratory. This might explain the discrepancy between these results and those in which distraction had a dynamogenic effect.

That two mental functions may be employed simultaneously and yet not interfere with one another, but exert a mutually beneficial effect has been proved by an experiment of Travis (49) on changes in auditory acuity during the performance of certain mental tasks. All nine subjects showed a lowered auditory limen, and this was most striking during the hardest work, *i.e.*, mathematical problems.

That the interruption of work is not necessarily a detriment has been demonstrated by a few studies. In fact, some investigators find that shifts from one task to another are as beneficial as rest pauses. In industrial situations they may be more so, for rest pauses are not always beneficial. Thus Burnett (5), experimenting with four girls engaged in cross stitching, found that 16 per cent less work was done on Friday when frequent rests occurred, than on Tuesday with no rests. One wonders how much time of week had to do with it. Others, of course, as Farmer and Bebbington (16), got increased efficiency from introducing rest periods. Yet Miles and Skilbeck (37), by introducing a fifteen minute period of change of work twice a day increased the output of one group of workers 14 per cent, a larger increase than was obtained from the same amount of rest; and Wyatt (57) obtained an increase of 7 to 12 per cent in the efficiency of another group by letting them work on one task during half the morning and afternoon, and another task during the latter half. Apparently a subtle difference in attitude toward the varied tasks accounts for the improvement in these cases.

As has been previously suggested, such an apparently extrinsic factor as chronology may influence efficiency. Laird (33) has shown this in his study of the effects of both time of day and day of week

on the performance of 112 college students in reading, grasping the meaning of what they read, and recalling it later. He found that their performance gradually approached a peak on Wednesday, and abruptly declined on the day following to a low level. During any one day, there was a gradual decline from 8 A.M. to 5 P.M., then a spurt from 8 P.M. to 10 P.M., and a drop thereafter. Habit no doubt accounts for this in part, though the work of Travis (51) on muscle tonus shows that the body musculature is at its highest tonus at the hours of retiring, or about the time when Laird obtained a spurt in efficiency. It would be interesting to know whether Travis got his maximum day to day tonus on Wednesdays. He reports wide day to day fluctuations.

Studies of Dawson (6) on school children, and of Whiting and English (55) on college students seem to give results at variance with those of Laird. Dawson gets a constant level of efficiency throughout the day with a possible increase in output at 3:30 of 10 per cent which he attributes to habit. English reports no clear differences in diurnal level. Previous investigators have reported a gradual rise during the forenoon, a drop at noon and after dinner, followed by a rise in the early afternoon. Evidently no definite trend can be demonstrated which will hold constant for different ages, conditions and types of work.

B. Motivation

An increasing number of studies has been carried out during the last six years upon the influence of those subtle factors involved in the mental attitude of the worker, which are included under the terms "set" and "motivation."

Encouragement and discouragement as incentives were compared by Gates and Rissland (18) in a study on the effect of complimentary and disparging remarks on performance. A group of college women were tested individually in speed of naming colors and tapping; then one third of them were complimented on their results, one third received adverse criticism, and to one third nothing was said. Each subject then repeated the test. Comparison of scores shows that a slight gain resulted from either type of criticism, except in the case of the poorer performers who were detrimentally influenced by disparagement. Hurlock (23), on the other hand, working with 100 boys and girls from nine to twelve years, in arithmetic, found that her boys improved most under reproof, while her girls showed the greatest

gain under praise, and reacted adversely to reproof. Laird (31) finds that college students respond better to positive than to negative incentives, and high school students the same. Probably the discrepancies in these results are due to differences in the exact nature of the incentives, their intensity, the person administering them, and the sex, age, and intelligence of the subjects. That there is a limit to the amount of disparagment that an individual can stand with equanimity is shown in Laird's study (32). He found that college students under severe razzing lost in steadiness and speed of tapping.

Punishment in the shape of an electric shock has proved effective in both animal and human situations. Kuo (30) found it more effective with rats in a multiple choice problem than confinement or a shorter path to food. Rexroad (43) found that it reduced errors in a human continuous multiple choice reaction to colors. His punished group showed 15 per cent greater accuracy than his unpunished groups. He finds three effects of punishment—disruptive, incentive, and instructive. These effects are strongest after practice has been brought to a high point. The disruptive effect offsets the advantage of punishment at first, but loses its influence later. Johansen (25), investigating the influence of incentive and punishment on reaction time to sound stimuli, got a reduction of 15 per cent in time. He explains it as being due to the increased expectancy of attention.

If the incentive appeals to a motive which is deep rooted enough, no amount of obstacles will thwart its effect. Knight and Remmers (29) studied the effect of severe hazing on the performance of a group of college fraternity pledges. Where the subjects were told their chances of acceptance in the fraternity depended on their performance in the tests given, they were able to overcome the severe physical and mental strain of the hazing, and do twice as many problems in computation per minute as a control group of juniors lacking the same incentive. Kitson (27) desired to find out how much a group of hand compositors in a Chicago printing establishment would improve their output under the stimulus of a cash bonus for extra productivity. The men had an average of 10 years' experience, yet after five months under the new wage stimulus their output was improved 67 per cent.

Competition, arousing the tendency to emulate others, is a powerful facilitator. Whittemore (56) working with twelve Harvard students, used as a task, printing with individual rubber types, para-

graphs from the press. Under one condition, they were to do as much as possible consistent with quality; under the other, to beat their fellow workers. They all turned out more work when competing, average 26 per cent, but the quality fell off, in this case.

C. Attitude

The attitude or "set" of the mental worker has a great influence on his efficiency. Myers (39) declares, in discussing the forms of fatigue, "It is attitude which finally breaks down in mental work." This vaguely defined factor of will, together with the controlling and directive sets used in complicated mental operations are among the most vital elements in efficiency. Thus Mayo (36) found that the low level of productivity in a certain industry was due to the pessimistic daydreams indulged in by the workers during their operations. By removing the causes of their pessimistic attitude, and introducing rests during which a happier train of thought was established, he raised their output 70 or 80 per cent and removed the heavy labor turnover. Yet Sullivan (47), in her study of mood in relation to performance, found only low correlations between transient affective states and performance of college students. The test conditions gave a strong enough drive to overcome mood. Book (4) studied the influence of this factor of "will" on the capacity of 124 college students to benefit from prolonged practice, in simple perceptual tasks. The tasks involved crossing out letters, two place multiplications, etc. One group were kept in ignorance of their score, the other group being kept posted and encouraged to outstrip themselves. He found that the stimulated section made more rapid and continuous gain; that gain ceased on removal of stimulus; and that groups showing no gain without it, would leap ahead when it was introduced.

One type of set, the "quantitative set," has been neglected. The author of this review in an unpublished experiment attempted to determine to what extent a mental worker's efficiency is influenced by the size of the task with which he is confronted. Various lengths of task were presented at different times to forty subjects, the work consisting of adding pairs of digits. It was found that a direct relation exists between the size of the task presented and the decrement in output. The longer the task, the steeper the decrement. A measure of the amount of tension exerted under the different quantitative sets showed that the lower level of output in the longer sets was partly due to a lessened expenditure of muscular effort.

That the degree of muscular tension under which the mental worker performs his task determines to some extent his output was demonstrated by the author (3) in a series of experiments. The subjects' normal tension was increased by grasping and squeezing Smedley dynamometers with weakened springs. The mental tasks included learning nonsense syllables, addition, letter naming, etc. Forty subjects took part. A gain in time and accuracy resulted as compared with the control condition without tension. Moreover the tension seemed most effective when the subject reached a point of fatigue. Practice did not reduce the effectiveness of tension. Evidently muscular tension is an important element in mental effort. Miller (38) has shown that when the muscles are relaxed, sensation intensity is reduced, and involuntary responses are reduced in extent.

Attention, defined subjectively, is a facilitator also. Newhall (41) recently demonstrated that intensity of cutaneous pressure and visual brightness vary with the degree of attention. Tuttle (52) found that the average height of the knee jerk of many subjects was ten times greater when he was attending to problems than otherwise.

Many cases of facilitation and inhibition can be traced to some subtle form of suggestion. Investigators of the effects of tobacco and drugs on efficiency have taken extreme pains to eliminate this factor. Dorcus (13) found an actual quickening effect on the pulse and blood pressure from smoking an empty cigarette holder, although the effect was much less than when tobacco was present.

Individuals working in groups or before an audience show characteristic differences in performance. Thus Travis (50) reports a study of the influence of an audience on eye-hand coördinations. The individual scores are considerably raised by the social situation. Sengupta and Sinha (44) tested five subjects in cancellation of A's from newspaper clippings. Facilitation was gained by working in the presence of others, a fact which the authors attribute to heightened attention. Negative results are reported by Gates (17) working with three groups of college women, one of which had only the experimenter present on the retest, one had six observers, and one had an audience of thirty-seven. The audience caused no significantly greater or less gain on the retest. Possibly the practice gained from the first taking of the test lessened the influence of the audience.

REFERENCES

1. Atkins, E. W., Efficiency of the Eye Under Different Intensities of Illumination. *J. Comp. Psychol.*, 1927, **7**, 1–12.
2. Bethel, J. P., An Experimental Investigation of the Influence of Certain Weather Conditions Upon Short Periods of Mental Work. *Amer. J. Psychol.*, 1925, **36**, 102–112.
3. Bills, A. G., The Influence of Muscular Tension on the Efficiency of Mental Work. *Amer. J. Psychol.*, 1927, **38**, 227–251.
4. Book, W. F., The Will to Learn. *Ped. Sem.*, 1922, **29**, 306.
5. Burnett, I., An Experimental Investigation of Repetitive Work. *J. Nat. Inst. Indust. Psychol.*, 1924, **2**, 18–23.
6. Dawson, S., Variations in Mental Efficiency of Children During School Hours. *Brit. J. Psychol.* (Gen. Sect.), 1924, **14**, 362–369.
7. Diserens, C. M., *The Influence of Music on Behavior*. Princeton, 1926.
8. Dockeray, F. C., Attention, Distraction and Fatigue. *J. Comp. Psychol.*, 1922, **2**, 331–370.
9. Dodge, R., The Problem of Inhibition. *Psychol. Rev.*, 1926, **33**, 1–12.
10. ———, Adequacy of Reflex Compensatory Eye Movements, Including the Effects of Neural Rivalry and Competition. *J. Exper. Psychol.*, 1923, **6**, 169–181.
11. ———, Habituation to Rotation. *J. Exper. Psychol.*, 1923, **6**, 1–35.
12. ———, Theories of Inhibition I. *Psychol. Rev.*, 1926, **9**, 106. Theories of Inhibition II. *Psychol. Rev.*, 1926, **9**, 167.
13. Dorcus, R., Effect of Suggestion and Tobacco on Pulse Rate and Blood Pressure. *J. Exper. Psychol.*, 1925, **8**, 297.
14. Ermanski, J., Das problem des arbeitsrhythm. *Prak. Psychol.*, 1923, **4**, 165–174.
15. Farmer, E., Economy of Human Effort in Industry. *J. Nat. Inst. Indust. Psychol.*, 1922, **1**, 18.
16. Farmer, E., and Bebbington, S. M., An Experiment in the Introduction of Rest Pauses. *J. Nat. Inst. Indust. Psychol.*, 1922, **1**, 89–92.
17. Gates, G. S., Effect of an Audience on Performance. *J. Abn. Psychol. & Soc. Psychol.*, 1924, **18**, 334–344.
18. Gates, G. S., and Rissland, L. O., The Effect of Encouragement and Discouragement Upon Performance. *J. Educ. Psychol.*, 1923, **14**, 21–26.
19. Gatewood, E. L., An Experiment in the Use of Music in an Architectural Drafting Room. *J. Appl. Psychol.*, 1922, **5**, 350–358.
20. Gilliland, A. R., and Moore, H. T., The Immediate and Long Time Effects of Classical and Popular Phonograph Selections. *J. Appl. Psychol.*, 1924, **8**, 309–323.
21. Herrick, C. J., *Neurological Foundations of Behavior*, 1924. Pp. 263.
22. Hull, C. L., The Influence of Tobacco Smoking on Mental and Motor Efficiency. *Psychol. Monog.*, 1924, **33**, No. 3, 1–160.
23. Hurlock, E., An Evaluation of Certain Incentives Used in School Work. *J. Educ. Psychol.*, 1925, **16**, 145–159.
24. Hyde, I. H., The Effect of Music on Electro-Cardiograms and Blood Pressure. *J. Exper. Psychol.*, 1924, **7**, 213–224.

25. JOHANSEN, A. M., Influence of Incentives and Punishment on Reaction Time. *Arch. Psychol.*, 1922, **8**, No. 54.

26. JOHNSON, H. M., Speed, Accuracy, and Constancy of Response to Visual Stimuli as Related to the Distribution of Brightness Over the Visual Field. *J. Exper. Psychol.*, 1924, **7**, 1–45.

27. KITSON, H. D., A Study of the Output of Workers Under a Particular Wage Stimulus. *Univ. J. of Business*, Nov., 1922.

28. KLINE, L. W., An Experimental Study of Associative Inhibition. *J. Exper. Psychol.*, 1921, **4**, 270–299.

29. KNIGHT, F. B., and REMMERS, H., Fluctuations in Mental Product When Motivation Is the Main Variable. *J. Appl. Psychol.*, 1923, **7**, 209–224.

30. KUO, Z. Y., The Nature of Unsuccessful Acts and Their Order of Elimination in Animal Learning. *J. Comp. Psychol.*, 1922, **2**, 1–29.

31. LAIRD, D. A., How the College Student Responds to Different Incentives to Work. *Ped. Sem.*, 1923, **30**, 366–370.

32. ———, Changes in Motor Control and Individual Variations Under the Influence of Razzing. *J. Exper. Psychol.*, 1923, **6**, 236–246.

33. ———, Relative Performance of College Students as Conditioned by Time of Day and Day of Week. *J. Exper. Psychol.*, 1925, **8**, 50.

34. ———, The Cost of Industrial Noises. *Indust. Psychol.*, 1927, **3**, 269–270.

35. MCDOUGALL, W., The Hypothesis of Inhibition by Drainage. *Psychol. Rev.*, 1926, **33**, 370–380.

36. MAYO, E., Revery and Industrial Fatigue. *J. Personnel Research*, 1924, **3**, 273–281.

37. MILES, G. H., and SKILBECK, O., An Experiment on Change of Work. *J. Nat. Inst. Indust. Psychol.*, 1923, **1**, 236–239.

38. MILLER, M., Effects of Varying Degrees of Relaxation Upon the Involuntary Response to an Electrical Shock. *J. Exper. Psychol.*, 1926, **9**, 26.

39. MYERS, C. S., The Study of Fatigue. *J. Personnel Research*, 1925, **3**, 321–334.

40. ———, Conceptions of Fatigue and Adaptation. *Psychol. Rev.*, 1925, **32**, 1–16.

41. NEWHALL, S. M., Effects of Attention on Intensity of Cutaneous Pressure and on Visual Brightness. *Arch. Psychol.*, 1923, **9**, No. 61.

42. PRESSEY, S. L., The Influence of Color Upon Mental and Motor Efficiency. *Amer. J. Psychol.*, 1921, **32**, 326–356.

43. REXROAD, C. N., Administering Electric Shock for Inaccuracy in Multiple Choice Reactions. *J. Exper. Psychol.*, 1926, **9**.

44. SENGUPTA, N., and SINHA, C., Mental Work in Isolation and in Groups. *Indian J. Psychol.*, 1926, **1**, 106–110.

45. SMITH, R. D., Sorting Mail to Music. *Lit. Dig.*, 1922, **72**, No. 9, 22–23.

46. SPENCER, L. T., The Validity of Heyman's Law. *Amer. J. Psychol.*, 1925, **36**, 427–433.

47. SULLIVAN, E., Mood in Relation to Performance. *Arch. Psychol.*, 1922, **22**, No. 53.

48. TINKER, M., A Study of the Relation of Distracted Motor Performance to Performance in an Intelligence Test. *Amer. J. Psychol.*, 1922, **33**, 578.

49. TRAVIS, L. E., Changes in Auditory Acuity During the Performance of Certain Mental Tasks. *Amer. J. Psychol.*, 1926, **37**, 178.
50. ———, The Effect of a Small Audience on Eye-Hand Coördination. *J. Abn. Psychol. & Soc. Psychol.*, 1925, **20**, 142–146.
51. TRAVIS, R. C., A Study in the Measurement of Muscle Tonus and Its Relation to Fatigue. *J. Exper. Psychol.*, 1924, **7**, 201–212.
52. TUTTLE, W. W., Effect of Attention on Patellar Tendon Reflex. *J. Exper. Psychol.*, 1924, **7**, 401.
53. VERNON, H. M., Fatigue and Efficiency in the Iron and Steel Industry. *Rep. Indust. Fatigue Res. Board*, 1921, **5**, No. 2.
54. WESTON, H. C., An Investigation into the Linen Weaving Industry. *Rep. Indust. Fatigue Res. Board*, 1921, **4**, No. 20.
55. WHITING, H. F., and ENGLISH, H. B., Fatigue Tests and Incentives. *J. Exper. Psychol.*, 1925, **8**, 33–49.
56. WHITTEMORE, I. C., The Influence of Competition on Performance. *J. Abn. Psychol. & Soc. Psychol.*, 1924, **19**, 236–254.
57. WYATT, S., Monotony. *J. Nat. Inst. Indust. Psychol.*, 1924, **2**, 24–30.

SOME PHYSIOLOGICAL CONDITIONS OF EFFICIENCY

BY CHESTER W. DARROW

The Institute for Juvenile Research [1]

This review will deal with recent studies of the effects of such things as drugs, diet, internal secretions, and atmospheric conditions upon the "psychological" behavior of normal subjects. The effects of these conditions upon the simple reflexes and the more extreme of abnormal phenomena may be found elsewhere in treatises on physiology, pharmacology, pathology, and internal medicine. The reviews in this journal by Poffenberger (111), Meyer (93), Robinson (114), Rickimaru (115), and Johnson, Swan and Weigand (65) are taken as the point of beginning for the present article.

Drugs

Alcohol: The question has been raised regarding the toxicity of the lesser quantities and concentrations of alcohol. Hollingforth (59, 60) investigated the effects of two amounts of 3.75% beer, using as control conditions a drink of similar composition without alcohol, and a "blank." Steadiness, tapping, coördination and substitution tests were impaired slightly for the smaller dose and more markedly for the larger, while color-naming and opposites tests gave conflicting results. A rise in pulse rate and a decrease in steadiness and coördination appear not solely a function of the alcohol, for they were observed after the nonalcoholic drink and after a meal. Miles (94) obtained somewhat similar results employing fruit juice to dilute the alcohol and as a control. He rubbed the rim of the glass with alcohol in the endeavor to deceive the subjects. Typing efficiency, verbal responses and ocular reactions were impaired according to the size of the dose. Gylys (54) used a single amount of alcohol in different degrees of dilution and found the deterioration greater for the higher concentrations. Results indicating some deterioration in one subject were obtained by Meyer (92) in a preliminary study of drug effects upon

[1] This is one of a series of articles prepared by members of the staff of the Illinois Institute for Juvenile Research, Chicago. Series C, No. 108.

the learning of shorthand. McDougall and Smith (87), continuing an earlier investigation, found lessened efficiency on the dotting machine and a decreased rate of alternation for ambiguous perspectives. This latter effect is regarded by McDougall as an indication of impaired cerebral functioning, but the fact that alcohol has been shown to affect the ocular reflexes probably makes the assumption of a "central" influence unnecessary. These recent studies give little evidence that there is a definite sequence in which activities are affected; they indicate rather a gradually increasing effect upon the "higher" as well as the "lower" processes. Pulse rate and blood pressure are generally increased.

Numerous incidental factors are found to be of importance. Habituation to alcohol is found by Miles (94) and Riegel (116) to cause greater rather than decreased impairment. Food consumed previously to drinking lessens the effect. Suggestion and personal prejudices, as we have already noted, are factors which most investigators try to eliminate by masking the control and test conditions, but the subjective effects of large doses are not easy to conceal. The influence of the subjects' knowledge under these conditions, therefore, remains an uncontrolled factor. The mild euphoria which so frequently follows alcohol, with the accompanying feeling that the performance is as good or better than usual, has not been sufficiently taken into account. Just as distraction and a sense of increased difficulty may occasion greater effort and consequently better performance on the part of a subject, it seems possible that euphoria and a sense of easy proficiency may be a factor in producing a lowered score on the tests. In attempting to locate the seat of certain motor accompaniments of alcohol narcosis, Kure *et al.*(69) removed the cerebellum from dogs and produced a gait closely resembling that due to alcohol. This he regards as some evidence that the drug has cerebellar effects. Athanasiu (11) found a decrease in the frequency of the electrical oscillations in the nerve and muscle very similar to that from fatigue. That alcohol reduces susceptibility to stimulation by its lipoid solvent action on the cell membranes seems fairly well established. It is significant that Miles found a correlation between the concentration in the blood or urine and impairment on the tests.

We merely mention a few of the recent articles dealing with closely related topics. The physiological aspects of alcoholism have been discussed by Mellanby (89), Starling (132), Wallace (146), Daniel (32), Osborne (104), Sollmann (129), and Weeks (150). The psychiatric significance of alcoholism has been treated by

MacCurdy (83), Pierce (110), and Wolfensberger (153). An actuarial study by Pearl (106), indicating an increased life expectancy for moderate drinkers as compared with either abstainers or heavy drinkers, is of interest in relation to older studies by Karl Pearson (107) and Phelps (109). Criminological aspects of alcoholism are presented by Rowe (117) and Anderson and Leonard (8).

Tobacco smoke: In addition to the difficulty of eliminating factors such as preconceived notions and suggestion, we have in studies of tobacco the additional problem of providing the subject with the comfortable distraction sometimes claimed for the purely mechanical act of smoking. Numerous attempts to obtain a satisfactory control have been described in recent articles. Froeberg (51), in the early part of an experiment, tried having the subject draw the control smoke through cotton wool in order to remove the nicotine, but this changed the appearance of the smoke and he abandoned the method. Hull (64) employed two similar pipes, the control having an electric coil through which the smoker drew moist heated air. The subjects were blindfolded and informed that the experiment was to test whether or not blind persons enjoyed smoking. The pipe was always held by the experimenter who furnished abundant olfactory stimulation from a pipe of his own. An illusion of smoking was produced in the majority of subjects. The tobacco condition produced an increase in pulse rate accompanied by tremor and disappearance of muscular fatigue, especially among the nonsmokers. Tapping, cancellation, reading reaction time, adding and speed of learning gave somewhat dubious results, smokers and nonsmokers in some cases reacting differently. Memory span and rote learning were affected unfavorably. The study is reported along with related material by O'Shea (103). Fisher (49) criticizes the technique of Hull, and in the latter part of his own experiment uses as controls both a "nicotineless" cigar and a nonsmoking condition. He finds a decrease in late and wrong responses to a complicated stimulus pattern following a regular cigar, and a somewhat smaller increase in efficiency after the "nicotineless" smoke. Dorcus (37) employed hypnotized subjects in the attempt to render the effects of suggestion equal for control and test conditions. The subjects were led to believe that they were smoking when they drew air through cigarette holders containing a lighted or an unlighted cigarette. The typical rise in pulse rate and in blood pressure was obtained for the lighted cigarette but not for the control, and Dorcus concludes that the changes ordinarily observed following tobacco smoking are due not

to suggestion but to physiological causes. This method will prove especially valuable if it is possible to obtain satisfactory records of performance during hypnosis. Of course the question will be raised as to the extent to which the subject may apprehend and adjust to the nonsmoking conditions by reaction systems not under the control of the operator.

With no attempt to deceive the subject as to the control and test conditions Froeberg found a loss of efficiency in muscular precision, steadiness, memory span, association, adding, and completion tests. Carver (27) and Bates (15) likewise noted a deterioration in motor coördination, but Carver obtained an increased facility in verbal reactions. Fisher (49) found a slight improvement in cancellation resulting from one-half to one-third of a cigarette. In this case it is to be considered that there is a higher efficiency and pulse rate on the preliminary tests on the smoking days than for the same tests on nonsmoking days. It seems likely that this is due to the anticipation of the smoking or inhaling condition, a new experience [see Ruckmick (119)] for many of the subjects. If so, it shows the importance of masking the control and test conditions. Earp (42) compares smoking and nonsmoking college students to the advantage of the latter.

The narcotic action of tobacco appears in a study of the effect on the sensory threshold of the finger by Mendenhall (90). That stimulation rather than narcosis appears in so many studies of performance after tobacco is possibly owing (a) to the selective action of the drug in paralyzing the cardio-inhibitory center [Sollmann (129)] and (b) to the release of adrenin [Cannon (26)]. The increase in circulatory activity noted by all investigators is possibly a factor in producing the increase in efficiency in some activities, and perhaps, also in accounting for the conflicting results so frequently obtained.

The best known chemical constituent of tobacco is not the only one of pharmacological significance. An analysis by Armstrong (9) shows that 7 per cent of cigar smoke and about 1 per cent of cigarette smoke is carbonic oxide. There is evidence for wide individual differences in the tendency toward carbon monoxide absorption. An earlier study by Bush (24) indicates that not nicotine, but pyridine (in chemical tests often mistaken for nicotine) is the most toxic constituent of tobacco smoke.

Opium derivatives: Experimental study of the psychological significance of the opium group of alkaloids is limited, although the clinical and physiological contribution to our knowledge is somewhat

extensive. McDougall and Smith (87) find an increased facility in dotting and verbal memory when these two activities are tested separately, but when the subjects attempt to carry on both activities simultaneously there is marked inefficiency. This accords with the physiological effects involving progressive depression of the "higher" and temporarily increased activity of the "lower" functions [Sollmann (129)]. Evidence of exaggeration of the reflex responses is reported by Cohen and McGuigan (29). Heinekamp (57) and Van Leersum (142) observe that morphine produces a stiffening of the tails of rats and mice and a tenseness of the anal and bladder sphincters. The effect appears to be due to stimulation in the medulla oblongata, and is perhaps a factor in the constipation characteristic of morphine addiction. Articles of psychiatric significance by Dixon (35) and Wholey (152) describe some of the symptoms of addiction and deprivation.

Hypnotics and anesthetics: The hypnotic action of veronal (barbital), a urea derivative, is attributed by Sands (120) to a reduced cerebral circulation and a lowered oxygen and carbon dioxide exchange. Stearns (133) shows the resemblance to alcohol narcosis. Claude, Borel and Robin (28) note that etherization dispels the dissociative confusion of the schizophrenic but not of the dementia precox patient. The former answers questions intelligently during the period just before recovery from anesthesia.

Cocain: The drug acts locally as an anesthetic, affecting the sensory fibers chiefly. When it is injected into the circulation, the first effect is stimulation. DiMacco and Fiumara (34) found that it reduces choice reaction time and prolongs the rate of ocular accommodation to varying distances. Tatum, Atkinson and Collins (138) proved that in dogs and rabbits death from cocain is ordinarily occasioned by spasm of the respiratory center, but decerebration or administration of an hypnotic drug increased the nonlethal dose as much as 400 per cent. The authors regard this as evidence that cocain stimulates the cerebrum, which in turn acts upon the medullary center to cause disturbances in respiration. Marx (86) explains the addiction to cocain as due to the escape offered from a sense of insufficiency. He says there is a dissociation of libido. Frankel (50) admits that the drug may occasion a release from inhibitions, but denies that it is by any effect upon the "libido." Maier (84), Aronowitsch (10), and Kolb (68) treat of the psychiatric aspects of cocain addiction.

The frequent classification of drugs as stimulants and as nar-

cotics or depressants is a matter of convenience in discussion rather than an indication of any clear cut differences in types of drugs. In many cases a substance is stimulating or depressing in its action depending upon the amount that is consumed or the manner in which it is taken. As in the case of cocain just mentioned, locally the action is anesthetic, but the first systemic effect is one of stimulation. Furthermore, the action of drugs is so selective that while they may stimulate one mechanism they may at the same time depress another.

Caffeine: Perhaps no substance is more commonly used in this country for its stimulating effects than coffee. Allers and Freund (5) were interested in comparing the effects of caffeine upon the quality of various so-called "higher" processes. They found the typical acceleration, especially of those activities involving imagery, but no apparent facilitation in the reproduction of ideational material. According to another report (6) coffee increased the amount of overestimation of movements seen by the periphery of the retina. McDougall and Smith (87) found an increased rate of alternation in ambiguous perspectives following tea drinking. Meyer (92) noted increased efficiency in the learning of shorthand. That the rate of excretion of caffeine in the urine is not a factor in determining the susceptibility of different individuals to the drug is borne out by the work of Okushima (100). He also found that elimination occurs with the same facility whether the subject drinks tea or coffee, but he believes that other toxins in coffee, apparently products of roasting, are not excreted so readily. Powers (112) regards these latter substances as especially injurious in the "better" grades of coffee. They are, he states, largely removed by boiling.

Strychnine: Bremer and Rylant (20) explain the increased excitability following strychnine as due to changes in the chronaxies of the neurones. McDougall reports increased efficiency in dotting and faster alternation of ambiguous perspectives.

Mescalin (peyote): The stimulating action of mescalin upon the special senses is the occasion of its psychological interest. With the expectation of subjective visual effects similar to those described by eidetic subjects, Klüver (67) ate a number of mescal buttons and obtained color experiences of great variability and motility. These were apparently without peripheral cause and beyond voluntary control. Chromatic stimuli occasioned unusually vivid color experiences and prolonged after images. Effects upon the other senses appear to have been of minor importance. Fernberger (46) reported that after a large dose the colors in the peripheral vision were unusually

clear and saturated. Colored imagery appeared when the eyes were blindfolded, but it was not nearly so kaleidoscopic as that described by Klüver. There was an exaggeration of all kinesthetic experiences and a corresponding magnification of all spatial relations, especially in the visual perception of depth. An exaggeration of the sense of the passage of time is attributed to a rapidly changing focus of attention.

Santonine: The physiological and psychological effects are discussed by Marshall (**85**).

Internal Secretions

Of no less psychological significance than drugs are certain substances elaborated in the body which maintain the proper functioning of the organism, and in some cases act as messengers in the "humoral transmission" of impulses. Recent discussions of internal secretions by Campbell (**25**), Lisser (**79**), and Rickimaru (**115**) will be of interest.

Thyroid: The importance of the thyroid glands to psychology is due largely to the part they play in maintaining normal metabolic activity. Liddell and Simpson (**73, 74, 75**) demonstrated their importance for the intelligent behavior of sheep, first negatively by extirpation and the production of cretinism, and then positively by thyroid feeding and the alleviation of symptoms. Thyroidectomized animals, according to Lee (**71**), had less frequent oestrous cycles; according to Davenport and Swingle (**33**) their young were born smaller and were unsatisfactorily nourished by the mother's milk. Simpson (**123**) notes an unfavorable effect on gestation in the sheep, and Hammett (**55**) observed a similar influence on the rat.

Parathyroid: The convulsive behavior frequently following thyroidectomy is due generally to the unintentional removal of the closely associated parathyroid tissue, with consequent depletion of the calcium in the blood plasma. Whether parathyroid tetany is due to the increased irritability of the organism or to greater absorption of toxins from the intestines as suggested by Dragsted (**38**) and Luckhardt (**82**) does not appear. Both conditions might be expected to result from the increase in cell permeability accompanying calcium deficiency. Luckhardt and Goldberg (**82**) by the administration of calcium, and Collip (**30**), Lisser and Shepardson (**78**), and Fisher and Larson (**48**) by the use of extracts of the gland have alleviated the symptoms of parathyroid tetany.

Pituitary: Although the posterior portion of this organ produces the most striking stimulative effects upon the smooth musculature, it is the action of the anterior lobe which is of primary psychological importance. According to Smith (128a) hypophysectomy causes inhibition of growth, weakness, incoördination and general physical degeneration. These he finds are curable by transplantations but not by injection or feeding. Frequent transplantations of glandular tissue into an individual are shown by Smith (128b) to occasion sexual maturity as early as the normal time of weaning. No data are given on the results of breeding these young animals. This latter would be of interest because Blatz and Heron (18) found that although feeding of anterior pituitary produced distinct physical and mental superiority as determined by weight and the learning of a maze or problem box, it definitely inhibited the reproductive functions. Teel (140) noted similar effects on reproduction. Possibly differences in the success of separating the substances of the two lobes and in the age of the extract may account for some of the different results.

Pineal gland: Badertscher (13) reported no significant changes in the structure or behavior of white leghorn chicks from which the gland was removed. This is in contrast to McCord's earlier report (88) of the strikingly precocious development in dogs following the feeding of this tissue.

Adrenal glands: The medulla of the suprarenals when introduced into the circulation produces effects similar in almost all respects to the stimulation of the sympathetic nervous system. It is one of the most important of the hormone "messengers" of the body. The feeding of the cortical portion in a study by Blatz and Heron (18) decreased efficiency in the learning of a maze and a problem box and occasioned marked digestive disturbances. Menninger (91) reports similar digestive effects in hyperthyroid human cases.

Gonads—female: Perhaps there is something psychological in the fact that sex has been exceedingly prolific of psychological and physiological research. We can but present the trends of investigation. A hormone prepared from the Graefian follicles of the ovaries of pigs [Allen and Doisy (2)] and of hens [Allen, *et al.*(4)], when injected into the immature female or spayed rat, initiated the changes in the genital tract and in behavior characteristic of oestrum. Loewe (80) reported a revival of egg laying by superannuated hens. Wang (147), Bugbee and Simond (22), and Slonaker (126), using

the methods of excision and injection, found the hyperactivity of the female rat at oestrum and during the prime of sexual life to be a function of the ovarian secretion. Bugbee and Simond (23) found the increase in activity to be accompanied by a decreased bodily growth. Similar effects have been demonstrated by Lipschütz, *et al.*(76) and by Wang and Richter (148) when ovaries are transplanted into castrated males. The transfusion of body fluids between two females which Stone (135a) grafted together did not produce an interdependence in sexual functioning. The feeding of ovarian extracts according to Durrant (39) produced no effect.

A significant study of the monthly cycle of circulatory, muscular, and mental activity in women is reported by Eagleson (41). The premenstrual period shows a tendency toward a rise in blood pressure and lessened efficiency in steadiness, coördination, and mathematical tests. The menstrual period is typically characterized first by high, then by a low blood pressure and by an increase in general efficiency. During the intermenstrual period there is a further rise in blood pressure and efficiency. The observations of Hauptmann (56) on the whole confirm the findings of Eagleson.

Gonads—male: Although the average activity of male rats is only one half that of females [Hitchcock (58)], it was found by Hoskins (61, 62) that castration produced a 75 per cent reduction in their activity. Athanasiu and Pezard (12) obtained a reduction of 20 per cent in the action currents of the gastrocnemius muscle of capons as compared with the controls. The question of a possible antagonism between male and female sex hormones appears to Lipschütz (77) to remain unsettled. Such workers as Noble (102), Pezard, Sand and Caridroit (108), Zawadawsky (155), Moore (96), and Roxas (118) from successful transplantations of the testes into spayed females offer a large amount of evidence for an ensuing atrophy of the female structures and the development of male characteristics of body and behavior. The results of homo- and heterotransplantations of the testes into males in whom for some reason the hormone is deficient are characterized by all degrees of success from remarkable recoveries of strength, mentality, and sex desire, to absolute failure. In the majority of cases the benefit has been relatively temporary. Effects of suggestion have not been ruled out in the human cases. Hoskins (61) provides a detailed review of the success which has been attained.

Diet

The dependence of sexual activity and development upon a quantitatively and qualitatively adequate nutritional regime has been demonstrated in the case of the male rat by Stone (**135b**) and in the female rat by Evans and Bishop (**45**) and Slonaker and Caird (**125**). Inferior performance in a maze was demonstrated by Anderson (**7**) when rats were stunted by either quantitative or qualitative dietary deficiencies. Neurotic disturbances in human beings according to Ehrström (**44**) occur in Finland most frequently during the early spring when the vitamine content of the food is lowest.

Hunger

Using the speed of devouring their food as a criterion of hunger, Washburn (**149**) found no correlation with either the speed of running or the perfection of learning the maze. Moss (**97**) and Tsai (**141**) demonstrated the superiority of hunger to sex as a stimulus or "motive" in determining choice reactions. Mursell (**98**) points out that not merely stomach contractions but other physiological and psychological factors are of importance in determining behavior toward food.

Sleep

For this important material the reader is referred to the review in this journal by Johnson, Swan, and Weigand (**65**).

Atmospheric Conditions

Vernon (**143**) and Wyatt (**154**) have shown a relation between unfavorable atmospheric conditions surrounding the laborer, and his production. Bethel (**17**) studied the influence of weather upon short periods of mental work, but, owing to the multitude of factors which could not be controlled, obtained no very definite results. Volker (**144**) found that diurnal variations in circulation, respiration, and temperature are determined by local time conditions and are independent of solar position. Oxygen deprivation has been studied by Bagby (**14**) and Lowson (**81**) who obtained evidence for an impaired mental and physical performance similar in some respects to alcoholic intoxication. Sundstroem (**136**) reviews investigations on the effects of tropical climates. Lee (**72**) shows that low environmental temperature lengthens oestrous in the rat.

Bodily Chemistry and Build

Finally we may only mention the large amount of work that is being done to determine the psychological significance of the chemical substances such as creatinine, sulphur, phosphorus, uric acid, and cholesterol which are found in the organism. The reader is referred to reviews by Needham (101) and Bowman (19). In accordance with evidence that psychological and physiological growth is determined by certain glandular secretions, it is not surprising that mental characters should show some correlations with the proportions and contours of bodily structure. Naccarati (99) obtained some correlation between a "morphological index" and intelligence, and an investigation by Sheldon (127a, b) in some degree confirms his findings. Studies following the lead of Kretschmer and showing the psychiatric significance of bodily types are mentioned in the work of Klüver (66b), Van der Horst (156) and Mohr and Gundlach (95).

REFERENCES

1. Allen, C. N., Studies in Sex Differences. *Psychol. Bull.*, 1927, **24**, 294–304.
2. Allen, E., and Doisy, E. A., The Induction of a Sexually Mature Condition in Immature Females by the Injection of Ovarian Follicular Hormone. *Amer. J. Physiol.*, 1924, **69**, 577–588.
3. Allen, E., and Doisy, E. A., An Ovarian Hormone. *Amer. J. Physiol.*, 1924, **68**, 138. *J. Amer. Med. Assn.*, 1923, **81**, 819–821.
4. Allen, E., Whitsett, J. W., Hardy, J. W., and Knerbert, S. L., *Proc. Soc. Exper. Biol. & Med.*, 1924, **21**, 500–503.
5. Allers, R., and Freund, E., Zur Kenntnis der psychischen Wirkung von Arzneimitteln und anderen Stoffen. I. Die Wirkung des Kaffees. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1925, **97**, 748–769.
6. Allers, R., Freund, E., and Prager, L., Zur Kenntnis der Beeinflussung der Sinnesschärfe durch Kaffee. *Arch. f. d. ges. Physiol.*, 1926, **212**, 183–187.
7. Anderson, J. E., and Smith, A. H., The Effect of Defective Nutrition upon the Behavior of the Rat in a Maze. *Amer. J. Physiol.*, 1925, **72**, 209–210.
8. Anderson, V. V., and Leonard, C. M., Drunkenness as Seen Among Women in Court. *Ment. Hygiene*, 1919, **3**, 266–274.
9. Armstrong, H. E., Carbonic Oxide in Tobacco Smoke. *Brit. Med. J.*, 1922, **1**, 992–993.
10. Aronowitsch, G. D., Sozial-pathologische und experimentell psychologische Studien Über den Cocainismus. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1925, **97**, 20–52.
11. Athanasiu, J., Influence de la Fatigue et de l'alcohol sur l'energie nerveuse motrice. *J. de Physiol.*, 1924, **22**, 52–59.

12. Athanasiu, J., and Pézard, Influence de la castration sur l'energie nerveuse motrice. *C. r. Acad. de Sci.*, 1924, **178**, 874–876.
13. Badertscher, J. A., Results Following Extirpation of Pineal Glands in Newly Hatched Chicks. *Anat. Rec.*, 1924, **28**, 177–197.
14. Bagby, E., Psychopathology Under Low Oxygen Tension. *U. S. A. Air Medical Service*, 1920, **1**, 39–43.
15. Bates, R. L., The Effects of Cigar and Cigarette Smoking on Certain Psychological and Physiological Functions. *Comp. Psychol.*, 1922, **2**, 371–423; 1923, **3**, 37–50.
16. Benedict, F. G., The Alcohol Program of the Nutrition Laboratory, with Special Reference to Psychological Effects of Moderate Doses of Alcohol on Man. *Science*, 1916, **43**, 907–917.
17. Bethel, J. P., An Experimental Investigation of the Influence of Certain Weather Conditions upon Short Periods of Mental Work. *Amer. J. Psychol.*, 1925, **36**, 102–112.
18. Blatz, W. E., and Heron, W. T., The Effect of Endocrine Feeding upon Learning Performance of White Rats. *J. Exp. Psychol.*, 1924, **7**, 291–311.
19. Bowman, K. M., Blood Chemistry and Mental Disease. *Amer. J. Psychiat.*, 1923, **2**, 379–408.
20. Bremer, F., and Rylant, P., Nouvelles recherches sur le mécanisme de l'action de la strychnine sur le systéme nerveux central. *C. r. Soc. de Biol.*, 1925, **92**, 199–202.
21. Brouha, L., and Simmonet, H., Effets de l'injection d'extrait de liquide folliculaire chez les femelles impubères. *C. r. Soc. de Biol.*, 1925, **93**, 489–491.
22. Bugbee, E. P., and Simond, A. E., Endocrinology. *Bull. Assn. for Study of Internal Secretions*, 1926, **10**, 349–369.
23. Bugbee, E. P., and Simond, A. E., The Effects of Injections of Ovarian Follicular Hormone on Body Growth and Sexual Development of Male and Female Rats. *Endocrin.*, 1927, **10**, 360–369.
24. Bush, A. D., Tobacco Smoking and Mental Efficiency. *N. Y. Med. J.*, 1914, **99**, 519–527.
25. Campbell, C. M., Psychical Disturbances in Diseases of the Glands of Internal Secretions. *Endocrine*, 1925, **9**, 201–212.
26. Cannon, A. B., Aub, J. C., and Binger, C., Effect of Nicotine Injection on Adrenal Secretion. *J. Pharm. and Exp. Therapy*, 1912, **3**, 379–385.
27. Carver, D. J., The Immediate Psychological Effects of Tobacco Smoking. *J. Comp. Psychol.*, 1922, 279–302.
28. Claude, H., Borel, A., and Robin, G., Un nouveau Procédé d'investigation psychologique: l'éthérisation. *Encéph.*, 1924, **19**, 419–421.
29. Cohen, S. J., and McGuigan, The Effect of Morphine on the Respiratory Center. *J. Pharm. & Exp. Ther.*, 1924, **23**, 145.
30. Collip, J. B., The Internal Secretion of the Parathyroid Glands. *Proc. Nat. Acad. Sci.*, 1925, **11**, 484–485.
31. Collis, E. L., The Use of Alcohol by Industrial Workers. *Lancet*, 1922, **202**, 773.
32. Daniel, J. F., Alcohol from a Scientific Point of View. *Scient. Mo.*, 1924, **18**, 159–167.

33. Davenport, C. B., and Swingle, W. W., The Effect of Operations upon the Thyroid Glands of Female Mice on the Growth of Their Offspring. *Anat. Rec.*, **34**, 109.

34. Di Macco, G., and Fiumara, A., Modification du temps de reaction discriminante et d'accommodation sous l'influence de la cocaine. *Arch. Ital. de Biol.*, 1924, **78**, 187–210.

35. Dixon, W. E., The Drug Habit. *Brit. Med. J.*, 1923, **1**, 543–545.

36. Dodge, R., and Benedict, F. G., Neuromuscular Effects of Moderate Doses of Alcohol. *Proc. Nat. Acad. Sci.*, 1915, **1**, 605–608.

37. Dorcus, R. M., Effect of Suggestion and Tobacco on Pulse Rate and Blood Pressure. *J. Exper. Psychol.*, 1925, **8**, 297–309.

38. Dragstedt, L. R., Parathyroid Tetany. *Endocrin*, 1924, **8**, 657–665.

39. Durrant, E. P., Studies in Vigor, III. The Effect of Ovarian Extract Feeding on the Activity of Ovariectomized White Rats. *Endocrin*, 1925, **9**, 221–228.

40. Dworkin, S., and Finney, W. H., Artificial Hibernation in the Woodchuck. *Amer. J. Physiol.*, 1927, **80**, 75–81.

41. Eagleson, H. E., Periodic Changes in Blood Pressure, Muscular Coordination and Mental Efficiency in Women. *Comp. Psychol. Mono.*, 1927, **4**, No. 20. Pp. 63.

42. Earp, J. R., Tobacco, Health, and Efficiency: a Statistical Inquiry into the Physiological Effects of Smoking Tobacco. *Lancet*, 1925, **1**, 213.

43. Eckstein, A., Einfluss qualitativen Unternährung auf die Funktion der Keimdrüsen. *Arch. f. d. ges. Physiol.*, 1923, **201**, 16–24.

44. Ehrström, R., Frühlingsmüdigkeit. *Acta. Med. Scand.*, Suppl. VII, 1924, 43–49.

45. Evans, H. M., and Bishop, K. S., On the Relations Between Fertility and Nutrition. *J. Metab. Research*, 1924, **1**, 335–356.

46. Fernberger, S. W., Observations Taken on Peyote. *Amer. J. Psychol.*, 1923, **34**, 267–270.

47. Fisher, H., Die Wirkungen der Kastration auf die Psyche. *Ztsch. f. d. ges. Neurol. u. Psychiat.*, 1924, **94**, 275–300.

48. Fisher, N. F., and Larson, E., Effects Produced by Extracts of Parathyroid Glands on Normal and Parathyroidectomized Dogs. *Amer. J. Physiol.*, 1925, **75**, 93–106.

49. Fisher, An Experimental Study of the Effects of Tobacco Smoking on Certain Psycho-Physical Functions. *Comp. Psych. Mono.*, 1927, **4**, No. 19. Pp. 50.

50. Fränkel, F., Bemerkungen zu Marx's Beitrag zur Psychologie der Kokainomanie. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1923, **85**, 61–65.

51. Froeberg, S., Effects of Smoking on Mental and Motor Efficiency. *J. Exper. Psychol.*, 1920, **3**, 334–346.

52. Gans, M., and Hoskins, R. G., The Fatiguability of Castrated Rats. *Endocrin.*, 1926, **10**, 56–63.

53. Gertz, E., Untersuchung über die Reizschwellen des Caffeins und Theobromins. *Skand. Arch. f. Physiol.*, 1923, **44**, 129–142.

54. Gylys, A., Die Beeinflussung der Geistiger Arbeit durch verschiedene Konzentrationen von Alkohol. *Psychol. Arb.*, 1925, **9**, 157–194.

55. HAMMETT, F. S., Studies of the Thyroid Apparatus, XI. The Effect of Thyroparathyroidectomy on Reproduction in the Albino Rat. *J. Metab. Research*, 1922, **2**, 417–427.

56. HAUPTMANN, A., Menstruation and Psyche. *Arch. f. Psychiat. u. Nervenkr.*, 1924, **71**, 1.

57. HEINEKAMP, W. J. R., The Morphine Mouse. *J. Pharm. Exper. Ther.*, 1922, **20**, 107.

58. HITCHCOCK, F. A., Studies in Vigor, V. The Comparative Activity of Male and Female Albino Rats. *Amer. J. Physiol.*, 1925, **75**, 205–210.

59. HOLLINGWORTH, H. L., When Is a Man Intoxicated? *J. Appl. Psychol.*, 1925, **9**, 122–130.

60. HOLLINGWORTH, H. L., The Influence of Alcohol. *J. Abn. Psychol. and Soc. Psychol.*, 1923, **18**, 204–237; 1924, **18**, 311–333.

61. HOSKINS, R. G., Studies in Vigor, IV. The Effects of Testicle Grafts on Spontaneous Activity. *Endocrin*, 1925, **9**, 277–296.

62. HOSKINS, R. G., The Effects of Castration on Voluntary Activity. *Amer. J. Physiol.*, 1925, **72**, 324–330.

63. MOUSSAY, B. A., and LEWIS, J. T., Etudes sur les hyperglycemies experimentales. Mechanisme Nerveux de l'action de la morphine. *C. r. Soc. Biol.*, 1923, **89**, 1120–1121.

64. HULL, C. L., The Influence of Tobacco Smoking. *Psychol. Mon.*, 1924, **33**, No. 3. Pp. 131.

65. JOHNSON, H. M., SWAN, L. H., and WEIGAND, G. E., Sleep. *Psychol. Bull.*, 1926, **23**, 482–503.

66a. KLÜVER, H., An Analysis of Recent Work on the Problem of Psychological Types *J. Nerv. and Ment. Dis.*, 1925, **62**, 6.

66b. KLÜVER, H., Psychological and Sociological Types. *Psychol. Rev.*, 1924, **31**, 456–462.

67. KLÜVER, H., Mescal Visions and Eidetic Vision. *Amer. J. Psychol.*, 1926, **37**, 502–515.

68. KOLB, L., Drug Addiction in Its Relation to Crime. *Ment. Hygiene*, 1925, **9**, 74–89; 1925, **9**, 699–724; 1925, **9**, 300–313.

69. KURE, K., *et al.*, Alcohol Intoxication and the Cerebellum. *Tokyo Igaku Zatshi*, **37**, No. 11: Abstract, *Psychol. Abst.*, 1927, **1**, 142.

70. LANGE, J., and SPRECHT, W., Neue Untersuchungen Über die Beeinflüssung der Sinnesfunktion durch geringe Alkoholmengen. *Zsch. f. Pathol.-psychol.*, 1915, **3**, 155–256.

71. LEE, M. O., Studies on the Oestrous Cycle in the Rat, II. The Effect of Thyroparathyroidectomy and Parathyroidectomy. *Endocrin*, 1926, **10**, 43–55.

72. LEE, M. O., Studies in the Oestrous Cycle in the Rat, III. The Effect of Low Environmental Temperatures. *Amer. J. Physiol.*, 1926, **78**, 246–253.

73. LIDDELL, H. S., and SIMPSON, S., Thyroid Therapy in Cretin Sheep. *Proc. Soc. Exp. Biol. and Med.*, 1922, **19**, 343–344; 1922, **19**, 423–425; 1922, **20**, 197–198.

74. LIDDELL, H. S., and SIMPSON, S., The Effect of Thyroid Therapy on Neuromuscular Mechanism of Sheep. *Quarterly J. Exper. Physiol.*, 1913, **13**, 191–197.

75. LIDDELL, H. S., and SIMPSON, S., Some Methods for Investigating the Neuromuscular Activity of Sheep. *Amer. J. Physiol.*, 1925, **72**, 63–68.

76. LIPSCHÜTZ, A., TIITSO, M., VOSS, H. E. V., VESJAKOV, S., and ADAMBERG, L., 1. Experimental Hermaphroditism and the Antagonism of the Sex Glands. *Arch. f. d. ges. Physiol.*, 1926, **211**, 621–697.

77. LIPSCHÜTZ, A., Is There an Antagonism Between the Male and Female Sex Endocrine Glands. *Endocrinology*, 1925, **9**, 109–116; *Arch. f. d. ges. Physiol.*, 1926, **211**, 697–721.

78. LISSER, H., and SHEPARDSON, H. D., A Case of Tetania Parathyroidpriva Treated with Collip's Parathyroid Extract. *Endocrin.*, 1925, **9**, 383–396.

79. LISSER, H., Organotherapy, Present Achievements and Future Prospects. *Endocrin.*, 1925, **9**, 1–21.

80. LOEWE, S., Voss, H. E., and PAAS, E., Uber weibliche Sexualhormone. *Arch. f. d. ges. Physiol.*, 1927, **215**, 453–456.

81. LOWSON, J. P., The Effects of Deprivation of Oxygen upon Mental Processes. *Brit. J. Psychol.* (Gen. Sec.), 1923, **13**, 417–434.

82. LUCKHARDT, A. B., and GOLDBERG, B., Preservation of the Life of Completely Parathyroidectomized Dogs. *J. Amer. Med. Assn.*, 1923, **80**, 79–80.

83. MACCURDY, J. T., General Etiological Factors in the Alcoholic Psychoses. *Brit. Med. J.*, 1922, **2**, 204–206.

84. MAIER, H. W., Allgemeines zur zentralen Cocainwirkung auf den Menschen. *Schweiz. med. Woch.*, 1925, **55**, 13–15.

85. MARSHALL, W., A Study of Santonin Zanthopsia. *J. Pharm. and Exper. Therap.*, 1927, **30**, 361–405.

86. MARX, N., Beiträge zur Psychologie der Cocainomanie. *Zschr. f. d. ges. Neur. u. Psychiat.*, 1923, **80**, 550–560.

87. MCDOUGALL, W., and SMITH, M., *The Effects of Alcohol and Some Other Drugs During Normal and Fatigued Conditions.* London: H.M. Stationery Office, Oxford Univ. Press, 1920.

88. MCCORD, C. P., The Pineal Gland in Relation to Somatic Sexual and Mental Development. *J. Amer. Med. Assn.*, 1914, **63**, 332–335.

89. MELLANBY, E., The Action of Alcohol on the Human Economy. *Brit. Med. J.*, 1922, **2**, 195–198.

90. MENDENHALL, W. L., A Study of Tobacco Smoking. *Amer. J. Physiol.*, 1925, **72**, 549–557.

91. MENNINGER, W. C., Effect of Epinephrin by Oral Administration. *J. Amer. Med. Assn.*, 1925, **84**, 1101–1102.

92. MEYER, M. F., Alcohol, Tobacco, and Tea. The Efficiency Under Drugs as Derived from the Learning Equation. *Amer. J. Psychol.*, 1923, **34**, 501–510.

93. MEYER, M. F., The Psychological Effects of Drugs. PSYCHOL. BULL., 1922, **19**, 173–182.

94. MILES, W. R., Action of Dilute Alcohol on Human Subjects. *Proc. Nat. Acad. Sci.*, 1924, **10**, 333–336.

95. MOHR, G. J., and GUNDLACH, R. H., The Relation Between Physique and Performance. *J. Exper. Psychol.*, 1927, **10**, 117–157.

96. Moore, C. R., On the Physiological Properties of the Gonads as Controllers of Somatic and Psychical Characters. *J. Exper. Zool.*, 1919, **28**, 137.
97. Moss, F. A., Study of Animal Drives. *J. Exp. Psychol.*, 1924, **7**.
98. Mursell, J. L., Contributions to the Psychology of Nutrition, I. Hunger and Appetite. *Psychol. Rev.*, 1925, **32**, 317–333.
99a. Naccarati, S., The Morphologic Aspect of Intelligence. *Arch. of Psychol.*, 1921, **45**.
99b. Naccarati, S., and Garrett, H. E., The Relation of Morphology to Temperament. *J. Abnormal Psychol. and Soc. Psychol.*, 1924, **19**, 254–263.
100. Okushima, K., Uber die Caffeinauscheidung im Harn, nachdem Tee und Kuffeetrinken beim Menschen. *Biochem. Ztsch.*, 1922, **129**, 563–569.
101. Needham, J., Lucretius Redivivus; The Hope of a Chemical Psychology. *Psyche*, 1927, **27**, 3–19.
102. Noble, G. K., The Production of Cloacal Glands in the Adult Female Desmognathus Fuscus by Testicular Transplants; The Change in Tooth Form in Adult Male by Castration. *Anat. Rec.*, 1926, **34**, 140.
103. O'Shea, M. V., *Tobacco and Mental Efficiency.* Macmillan, 1923.
104. Osborne, C. T., Harmfulness of Caffeine and Value of Alcohol in Old Age. *Med. J. and Rec.*, 1924, **120**, 163–164.
105. Paulsen, A. E., The Influence of Treatment for Nutritional Toxaemia on Mental and Motor Efficiency. *Arch. of Psychol.*, 1924, **11**, No. 69. Pp. 45.
106. Pearl, R., Alcohol and Life Duration. *Brit. Med. J.*, 1924, **1**, 948–950.
107. Pearson, K., and Edderton, E., *Eugenics Laboratory Memoirs*, 1910, **13**, 1–35.
108. Pézard, A., Sand, K., and Caridoit, F., Survie d'un Transplant actif en presence d'un ovaire producteur d'oeufs mûrs chez la poule domestique. *C. r. Soc. de Biol.*, 1924, **90**, 1459.
109. Phelps, E. B., *The Supposed Death Rates of Abstainers and Non-abstainers and Their Lack of Scientific Value.* New York: Thrift Pub. Co., 1913. (See also *Amer. Underwriters Mag. and Ins. Rev.*, N. Y., 1911, 36.)
110. Pierce, B., Mental States in Alcoholism. *Lancet*, 1924, **1**, 841–843.
111. Poffenberger, A. T., Drugs. Psychol. Bull., 1914, **11**, 418–421; 1916, **13**, 434–436; 1917, **14**, 408–411; 1919, **16**, 291–298.
112. Powers, H., The Syndrome of Coffee. *Med. J. and Rec.*, 1925, **121**, 745–747.
113. Rhode, E., Climacterium Verile. *Svensk Läkertidn.*, 1927, **24**, 3–13.
114. Robinson, E. S., Mental Work. Psychol. Bull., 1921, **18**, 456–482.
115. Rickimaru, Emotion and Endocrine Activities. Psychol. Bull., 1925, **22**, 205–258.
116. Riegel, A., Über Gewöhnung an Alkohol. *Psychol. Arb.*, 1922, **8**, 48–72.
117. Rowe, M. J., Alcohol and Crime. *J. of Delinquency*, 1919, **4**, 135–151.
118. Roxas, H. A., Gonads—Cross Transplantation in Sebright and Leghorn Fowls. *Proc. Soc. Exper. Biol. and Med.*, 1926, **23**, 789–793.
119. Ruckmick, C. W., Experiences During Learning to Smoke. *Amer. J. Psychol.*, 1924, **35**, 402–406.

120. SANDS, I. J., Veronal Intoxication. *J. Nerv. and Ment. Dis.*, 1923, **58**, 161–162.

121. SCHILLING, W., The Effect of Caffein and Acetanelid on Simple Reaction Time. *Psychol. Rev.*, 1921, **28**, 72–79.

122. SHERMAN, H. C., and CAMPBELL, H. L., Growth and Reproduction upon Simplified Food Supply. *J. Biol. Chem.*, 1924, **60**, 5–15.

123. SIMPSON, S., Thyro-parathyroidectomy in the Sheep. *Amer. J. Physiol.*, 1921, **55**, 281.

124. SIMPSON, S., The Effect of Pituitary Feeding on Egg Production in the Domestic Fowl. *Q. J. Exp. Physiol.*, 1923, **13**, 182–189.

125. SLONAKER, J. R., and CAIRD, T. A. *Amer. J. Physiol.*, 1923, **64**, 35–43.

126. SLONAKER, J. R., The Effect of Pubescence, Oestration and Menopause on the Voluntary Activity in the Albino Rat. *Amer. J. Physiol.*, 1924, **68**, 294–315; 1925, **71**, 362–394.

127a. SHELDON, W. H., Morphologic Types and Mental Ability. *J. Personnel Res.*, 1927, **5**, 447–451.

127b. SHELDON, W. H., Social Traits and Morphologic Types. *Personnel J.*, 1927, **6**, 47–55.

128a. SMITH, P. E., The Disabilities Caused by Hypophysectomy and their Repair. *J. Amer. Med. Assn.*, 1927, **88**, 158–161.

128b. SMITH, P. E., The Induction of Precocious Sexual Maturity by Pituitary Homeo-transplants. *Amer. J. Physiol.*, 1927, **4**, 227–233.

129. SOLLMANN, *Manual of Pharmacology*. 3rd Ed. Saunders, 1926.

130. STANDING, F. N., The Uplifted Veil: An Experience in the Dentist's Chair. *Psyche*, 1924, **4**, 227–233.

131. STANLEY, L. L., Morphinism and Crime. *J. Crim. Law and Criminol.*, 1918, **8**, 749–753.

132. STARLING, E. H., and others, *The Action of Alcohol on Man*. N. Y., Longmans, 1923. Pp. 291.

133. STEARNS, A. W., Veronal Intoxication. *J. Nerv. and Ment. Dis.*, 1923, **57**, 571–572.

134. STOCKARD, C. R., and PAPANICOLAON, C., Further Analysis of Degeneracy and Deformities by Descendants of Alcoholized Mammals. *Amer. Naturalist*, 1916, **50**, 65–88, 144–177.

135a. STONE, C. P., Preliminary Note on Rats Living in Parabiosis. *Endocrine*, 1925, **9**, 505–512.

135b. STONE, C. P., Delay in Awakening Copulatory Ability in the Male Albino Rat. I. Quantitative Deficiency, *J. Comp. Psychol.*, 1924, **4**, 195–224; II. Qualitative Deficiency, *J. Comp. Psychol.*, 1925, **5**, 177–203.

136. SUNDSTROEM, E. S., The Physiological Effects of Tropical Climate. *Physiol. Reviews*, 1927, **7**, 320–362.

137. SWALE, V., Current Views on Internal Secretions. *Physiol. Revs.*, 1927, **7**, 288–319.

138. TATUM, A. L., ATKINSON, A. J., and COLLINS, K. H., Acute Cocain Poisoning: Preliminary Report on an Experimental Study. *J. Amer. Med. Assn.*, 1925, **84**, 1177.

139. TAYLOR, C. K., Effect of Coffee Drinking Upon Children. *Psychol. Clinic*, 1912, **6**, 56–58.

140. TEEL, H. M., The Effects of Injecting Anterior Hypophyseal Fluid on the Course of Gestation in the Rat. *Amer. J. Physiol.*, 1926, **79**, 170–182.

141. TSAI, C., The Relative Strength of Sex and Hunger Motives in the Albino Rat. *J. Comp. Psychol.*, 1925, **5**, 407–415.

142. VAN LEERSUM, E. C., *Nederlandsch Tijdschrift voor Geneskunde.* Amsterdam, 1918, I.

143. VERNON, H. M., and BEDFORD, T., The Relation of Atmospheric Conditions to the Working Capacity and Accident Rate of Coal Miners. *Indus. Fatigue Research Board*, Rep. 39.

144. VÖLKER, H., Tagesperiodische Schwankungen einiger Lebensvorgange des Menschen. *Arch. f. d. ges. Physiol.*, 1926, **215**, 43–77.

146. WALLACE, G. B., Some Considerations of the Pharmacology and Therapeutic Value of Alcohol. *Med. Rec.*, 1922, **101**, 47–50.

147. WANG, G. H., The Relation Between Spontaneous Activity and Oestrous Cycle in the White Rat. *Comp. Psychol. Mon.*, 1923, **2**, No. 6.

148. WANG, G. H., and RICHTER, C. P., and GUTTMACHER, A. F., Activity Studies on Male Castrated Rats with Ovarian Transplants and Correlation with Histology of the Grafts. *Amer. J. Physiol.*, 1925, **73**, 581–599.

149. WASHBURN, M. F., Hunger and Speed of Running as Factors in Maze Learning in Mice. *J. Comp. Psychol.*, 1926, **6**, 181–187.

150. WEEKS, C. C., *Alcohol in Medical Practice with a Chapter on the Evolution of Medical Opinion.* London: H. K. Lewis and Co., 1925.

151. WERTHEIMER, F. I., and HASKETH, F. E., The Significance of the Physical Constitution in Mental Disease. *Med.*, 1926, **5**, 375–462; *Psychol. Abst.*, 1927, **1**, 152.

152. WHOLEY, C. C., The Mental and Nervous Side of Addiction to Narcotic Drugs: A Neuropsychiatric Problem. *J. Amer. Med. Assn.*, 1924, **83**, 321–325.

153. WOLFENSBERGER, M., Der Alkohol Wahnsinn und seine Beziehungen zu den Schizophrenien. *Zsch. f. d. ges. Neur. u. Psychiat.*, 1923, **83**, 385–418.

154. WYATT, S., FRASER, J. A., and STOCK, F. G., The Relation of Atmospheric Condition to the Working Capacity and Accident Rate of Coal Miners. *Indus. Res. Board*, Rep. No. 33. London: H.M. Stationery Office, 1926. Pp. 31.

155. ZAWADOWSKY, Sex and Development of Sex Characters, Moscow. Reviewed, *Endocrine*, 1923, **7**, 732.

156. VAN DER HORST, Experimentelle psychologische Untersuchungen zu Kretschmer's korperbau und Charakter. *Zsch. f. d. ges. Psychol.*, 1924, **93**, 341–380.

SPECIAL REVIEWS

THEODOR LIPPS, *Psychological Studies.* (2nd revised and enlarged edition, translated by Herbert C. Sanborn). Baltimore: Williams & Wilkins, 1926. Pp. 333.

This second volume of the Psychology Classics edited by Knight Dunlap, fills a need that has long been felt by the student of psychology whose reading of German is not too facile. This translation of 1905 edition of the *Psychologische Studien* is made by a former student of Lipps and leaves little to be hoped for in the way of translation. The volume has three parts: 1. The space of visual perception; 2. The nature of musical consonance and dissonance, and 3. The law of psychic relativity and Weber's Law.

SAMUEL W. FERNBERGER.

University of Pennsylvania

JEAN PIAGET. *The Language and Thought of the Child* (Preface by E. Claparède). N. Y.: Harcourt, Brace. 1926. Pp. xxiii+246.

The author presents a new point of view from a study of the language of the child. He finds that the mind of the child is composed of two levels: the lower is the plane of subjectivity which is most important during the first years of the child life and the higher is a plane of objectivity and logical ideas,—the plane of reality. This is developed slowly during the first years of the life of the child. The impression, which is quite common, that the child's mind presents a picture of confusion is due to the failure to realize that each of these planes has a logic of its own "which protests loudly at being coupled with that of the other."

The author presents his facts in a series of "clinical pictures." The reviewer found the book exceedingly interesting but rather a discussion of child logic than one of the psychology of child language and thought.

SAMUEL W. FERNBERGER.

University of Pennsylvania

BOOKS RECEIVED

E. MORRIS MILLER, *Brain Capacity and Intelligence.* Monograph Series, No. 4. Australasian Asso. of Psychol. & Philos., 1926. Pp. 79.

ANDRIES, H. D. MACLEOD, *Sur diverses questions se presentant dans l'etude du concept de realite.* Paris: Hermann, 1927. Pp. xi+239.

LOYD R. COLEMAN & SAXE COMMINS, *Psychology: A Simplification.* New York: Boni & Liveright, 1927. Pp. 320.

Teacher Training as a State Function. Report by the Teacher Training Committee of the Educational Council of the Ohio State Teachers Association. Columbus: 1927. Pp. 47.

EDWIN J. COOLEY, *Probation and Delinquency.* The Study and Treatment of the Individual Delinquent. New York: Catholic Charities of the Archdiocese of New York, 1927. Pp. xv+544.

CONRAD RICHTER, *Principles in Bio-Physics.* The Underlying Processes Controlling Life Phenomena and Inner Evolution. Harrisburg: Good Books Corp., 1927. Pp. 86.

FRED C. WALTERS, *A Statistical Study of Certain Aspects of the Time Factor in Intelligence.* New York: Teachers College, 1927. Pp. viii+82.

CHARLES M. MILLS, *Vacations for Industrial Workers.* New York: Roland, 1927. Pp. viii+328.

AUGUST KIRSCHMANN, *Psychologische Optik.* ADALBERT GREGOR, *Das psychogalvanische Phänomen.* Abderhalden's Handbuch der biologischen Arbeitsmethoden. Berlin: Urban & Schwarzenberg, 1927. Pp. 837–1174.

ERWIN WEXBERG, *Your Nervous Child.* (Translated by W. B. Wolfe). New York: A. & C. Boni, 1927. Pp. xiv+178.

K. S. GIBSON & F. K. HARRIS, *The Lovibond Color System.* Sci. Papers, Bur. Standards, No. 547. Washington: 1927. Pp. 46.

RAYMOND G. FULLER, *Fourteen is Too Early.* Some Psychological Aspects of School-Leaving and Child Labor. New York: Nat. Child Labor Comm., 1927. Pp. 40.

JESSE W. SPROWLS, *Social Psychology Interpreted.* Baltimore: Williams & Wilkins, 1927. Pp. xii+268.

A. T. POFFENBERGER, *Applied Psychology; Its Principles and Methods.* New York: Appleton, 1927. Pp. xx+586.

C. SPEARMAN, *The Abilities of Man: Their Nature and Measurement*. New York: Macmillan, 1927. Pp. viii+415.

MEHRAN K. THOMSON, *The Springs of Human Action*. New York: Appleton, 1927. Pp. xvi+501.

GRACE A. DE LAGUNA, *Speech: Its Function and Development*. New Haven: Yale University Press, 1927. Pp. xii+363.

NOTES AND NEWS

ON May 13–14 was held the second annual meeting of midwestern experimental psychologists at Northwestern University in Chicago. Both formal papers and informal reports of research were presented. At this meeting steps were taken to organize the group into the Midwestern Psychological Association. Professor A. R. Gilliland was elected president for the coming year. Over 200 psychologists were in attendance. The meeting next year will be held at the University of Wisconsin.

AT the University of Pennsylvania, the following promotions have been announced in the Department of Psychology: to professors of psychology, Samuel W. Fernberger and Karl G. Miller; to assistant professors of psychology, Henry E. Starr, Robert A. Brotemarkle and H. Sherman Oberly.

PROFESSOR C. A. RUCKMICK, of the department of psychology at the University of Iowa, will act as editor of the University of Iowa, will act as editor of the University of Iowa Studies in Psychology beginning with the forthcoming volume, No. XI.

DR. ERWIN A. ESPER has resigned as assistant professor of psychology at the University of Illinois to accept a position as associte professor of psychology at the University of Washington in Seattle.

AT a meeting of the Board of National Research Fellowships on May 27 and 28, the following additional appointments were made for psychology: reappointments, Harry R. De Silva, M. F. Metfessel, and R. H. Seashore; new appointments, C. P. Heinlein and Louis W. Max.